

EXPLORING MIDDLE SCHOOL STUDENTS' SYSTEMS LITERACY WITHIN  
THE CONTEXT OF WATER SYSTEM

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WITHIN THE CONTEXT OF WATER SYSTEM**

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## **ABSTRACT**

### **EXPLORING MIDDLE SCHOOL STUDENTS' SYSTEMS LITERACY WITHIN THE CONTEXT OF WATER SYSTEM**

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The purposes of this study are determined as to (1) provide a conceptual model for the description of 'systems literacy'; (2) propose an alternative framework for the elements of systems literacy in water system context; (3) explore possible factors that might interfere with systems literacy in water system context; and (4) determine readiness of children completing middle school degree in terms of systems literacy in water system context. A research cycle was designed including both conceptual research and empirical research. In conceptual research, philosophical conceptualization and conceptual systems were used as research methodology. To test the model and acquire in-depth information, multiple case study was selected. Accordingly, four 9<sup>th</sup> grade students were participated in the study. Data was collected through four-tiered conception test, two drawing tasks and semi-structure interviews. Based on the outputs of conceptual research, an alternative definition for systems literacy and systems literacy in water system context were provided. On the other hand, the analysis of empirical research indicated that 9<sup>th</sup> grade students in this study failed to develop an adequate level of critical systems literacy (CRSL) due to having limited

understanding either in functional (FSL) or cultural systems literacy (CUSL). While their CRSL were interacted with their FSL and CUSL, it also obscured by their alternative conceptions and in-situ answers. Possible factors interfered with three elements of systems literacy in water context were determined as gender, daily life experiences, socioeconomic status, residence area, cognitive differences, and parental interaction. To conclude, it is suggested that students' readiness of systems literacy should be determined before revising current elementary science education and education for sustainability curricula.

**Keywords:** Systems literacy, multiple case study, water cycle, middle school students, water system

## ÖZ

### SU SİSTEMİ BAĞLAMINDA ORTAOKUL ÖĞRENCİLERİNİN SİSTEM OKURYAZARLIKLARI ÜZERİNE BİR İNCELEME

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Mevcut çalışmanın amaçları (1) ‘sistem okuryazarlığı’ tanımına kavramsal bir model oluşturmak; (2) sistem okuryazarlığı kavramına su sistemi bağlamında bir alternatif çerçeve önermek; (3) su sistemi kapsamında tanımlanan sistem okuryazarlığı ile etkileşen olası faktörleri belirlemek ve (4) ortaokulu bitirmiş öğrencilerin su sistemi kapsamında sistem okuryazarlıkları ile ilgili hazırbulunuşluk seviyelerini tespit etmek olarak belirlenmiştir. Bu bağlamda hem kavramsal hem de deneysel araştırma basamaklarını içeren bir araştırma döngüsü tasarlanmıştır. Kavramsal araştırma çerçevesinde, ‘felsefî kavramsallaştırma’ ve ‘kavramsal sistemler’ metodolojileri kullanılmıştır. Oluşturan kavramsal model ve teorik çerçeveleri test etmek ve detaylı bilgi elde etmek adına nitel bir araştırma yöntemi olan çoklu durum çalışması seçilmiştir. Araştırmaya dokuzuncu sınıf seviyesinde dört lise öğrencisi katılmıştır. Çalışmanın verileri dört aşamalı kavram testi, iki adet çizim etkinliği ve yarı yapılandırılmış görüşme soruları ile toplanmıştır. Kavramsal araştırmanın sonuçlarına dayanarak sistem okuryazarlığı kavramı tanımı yapılmıştır. Ardından su sistemi bağlamında sistem okuryazarlığı kavramı ile ilgili bir teorik çerçeve sunulmuştur. Öte



yandan, deneysel araştırma analizleri sonucunda öğrencilerin eleştirel sistem okuryazarlık seviyelerinin işlevsel veya kültürel okuryazarlık seviyesindeki eksiklikler sebebiyle yetersiz olduğu gözlenmiştir. Eleştirel sistem okuryazarlıkları hem işlevsel ve kültürel okuryazarlıkları ile hem de öğrencilerin alternatif kavramları ve değişken yanlış cevapları sebebiyle etkileşmektedir. Bu etkileşimler, eleştirel okuryazarlığın gelişmesinde bir engel olarak nitelendirilebilir. Ek olarak, bazı olası faktörlerin de bireylerin sistem okuryazarlıkları ile ilişkili olduğu gözlemlenmiştir. Çalışmanın bulguları fen eğitimi ve sürdürülebilir kalkınma için eğitim programlarına sistem bilimlerini entegre etmek için sistem okuryazarlığı kavramının önemini ortaya çıkarmıştır. Sonuç olarak, eğitimcilere ve program geliştirme uzmanlarına, sistemsel okuryazarlık kapsamında bir entegrasyon öncesinde, bireylerin hazırbulunuşluk seviyelerini belirlemeleri önerilmektedir.

**Anahtar Kelimeler:** Sistem Okuryazarlığı, Çoklu Durum Çalışması, Su Döngüsü, Ortaokul Öğrencileri, Su Sistemi



*To my mother*

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## **LIST OF ABBREVIATIONS**

SL: Systems Literacy

FSL: Functional Systems Literacy

CUSL: Cultural Systems Literacy

CRSL: Critical Systems Literacy

ESD: Education for Sustainable Development



## CHAPTER 1

### INTRODUCTION

*“All scientists are systems scientists to one degree or another,  
even when they don’t know that.”*

*Mobus & Kalton (2015)*

Individuals, who involve somehow in any educational process, continually strive to find the answer to the following question: “What is the fundamental purpose of education?” Actually, it may be considered as an odd question itself at first glance since educators would be the ones who are expected to know the answer of this question and would educate generations based on the answer. However, the answer(s) is/are so complicated even though the question seems to be very clear, precise and simple.

Even though there have been a lot of comprehensive answers to this question, *literacy* (e.g., Dillon, 2009; Orr, 1994) and *behavior change* (e.g. Hungerford & Volk, 1990) has been two of the most frequently used terms within those answers. In every level of education including informal education as well, one of the aims is determined to increase the level of literacy (UNESCO, 2000; UNESCO, 2006). The simplest description for *literacy* is “... the ability to decode and comprehend written language at a rudimentary level, that is, the ability to look at written words corresponding to ordinary oral discourse, to say them, and to understand them” (Kaestle, 1985, p.13). However, the definition of literacy has been evolving in time and started branching and including some components. For instance, Williams and Snipper (1990) and Stables (1998) evaluated the definition of literacy in three elements as *functional literacy*, *cultural literacy* and *critical literacy*. Besides these elaborations –though

there are many others-, the frameworks of literacy have been discussing as an integral part of the purpose of education (e.g. DeBoer; 2000; Dillon, 2009) among educators.

The efforts of pursuing the purpose of education, accumulation of knowledge through history, and debates on the definitions and functions of literacy have been contributing to the development of literacy literature. Accompanied with these conventional definition(s), literacy appears in variety of forms in different contexts and open to reinterpretations (Kaestle, 1985). Although defining the traditional notion of literacy and its elements are still open to debate and continue evolving (for further discussions; Kress, 1997; and Stables & Bishop, 2001), these descriptions may be clustered around either *traditional literacy* (e.g., Kaestle, 1985; Stables, 1998) or *context-based literacy* such as scientific literacy (e.g., Mun et. al, 2015; Roberts, 2007b), environmental literacy (e.g., Hollweg et. al, 2011; Stables & Bishop, 2001), sustainability literacy (e.g., Nolet, 2009; Winter & Cotton, 2012) within the literature. Moreover, as in the other branches of social sciences, there is no consensus on the definition of each literacy and their possible elements.

The notion of context-based literacy brings with different variables to be identified while defining them. Simultaneously, possible components and their interactions within the contexts have been studied by the researchers (for extensive summaries in different contexts, please read Kress, 1997; Roberts, 2007b; Roth, 1992) so as to explore the nature(s) of literacy contexts and to contribute to raise citizens with higher level of literacy. Within the context of the study, systems literacy was chosen as one of the context-based literacies to be explored from an educator's perspective.

### **1.1. An Overview of Systems, Systems Science, Systems Thinking, and Systems Literacy**

The emergence of the term 'system' is dated back to 18th century when Immanuel Kant (as cited in Reynolds, 2011) firstly introduced the systems idea in his book, Critique of Pure Reason. On the other hand, the notion of 'systems science' was planted in early twentieth century (Hammond, 2003) when the dominance of reductionism in science were started to be debated (Mobus & Kalton, 2015). The roots

of systems science can be traced back to ‘General Systems Theory’ constructed by von Bertalanffy in 1920s (Mobus & Kalton, 2015) who strongly claimed that living things cannot be considered as entities that can be examined in terms of mechanical interaction of their elements. Especially after World War II, systems theory began evolving and integrated into different disciplines such as ecology, social sciences, and business management (Mobus & Kalton, 2015). Simultaneously, the term ‘systems thinking’ was being evolved in time with the development of systems and systems science since (1) scientists from different areas needs to explore how systems work, (2) a new discourse was introduced to explain systems such as feedback, chaos, and complexity (Hieronymi, 2013).

Current descriptions of ‘systems science’ and ‘systems thinking’ can be considered as products that different scientific disciplines have been contributing over the last century (Mobus & Kalton, 2015). Thus, much of the systems thinking studies (e.g. Ben-Zvi Assaraf & Orion, 2005a; Feriver, Olgan & Teksöz, 2019; Nolet, 2009) in educational literature embraced some of the principles of systems science. Different from other system scientists (e.g. von Bertalanffy, 1960; Mobus & Kalton, 2015), system thinking researchers intend to explore (1) how individuals in different ages perceive systems; (2) how can we use these perceptions to “effectively participate in and engage with them [systems]” (Henning & Chen, 2012, p.470, brackets added); and (3) how can we integrate systems thinking in educational context.

Systems thinking is included in science education as a component of scientific literacy (Mun et. al, 2015) and in educational for sustainable development (ESD) as one of the sustainability competencies (UNECE, 2011; Wiek et al., 2011) and as a component of sustainability literacy (Nolet, 2009; Warren, Archambault & Foley, 2014). Above and beyond, 21st century issues are also required systems thinking approach to examine and overcome the reasons and the effects of them (Richmond, 1993) and to promote sustainability of the planet. Due to these reasons, systems thinking can be considered one of the indispensable elements for educational context. However, when the elements of systems thinking as well as the nature of systems science are examined, the researcher of this study presumed that systems thinking is more than a thinking

process. It includes not only thinking about systems but also skills and competencies which may go beyond “thinking”. Moreover, system thinking also interferes with human systems whose have intangible elements as beliefs, goals, values and so on (Mobus & Kalton, 2015). Correspondingly, reframing systems thinking within a systems literacy perspective may provide a comprehensive concept in educational context so as to find key routes to deal with 21st global century issues.

Even though much of the existing literature in systems science preferred to use ‘systems thinking’, systems literacy have started to be pronounced around 2000s. Very first idea can be considered as the statement of a senior government advisor in the UK government’s Cabinet Office during 90s as “Clear systems thinking is one of the basic literacies of the modern world” (as cited in Reynolds, 2011, p.40). Reynolds added that “In the same way effective systems thinking is a literacy that is continually being informed, moulded and (re)shaped by ongoing practice.” Wood (2011) described systems literacy as “Systems literacy is an evolved form of interdisciplinary research practice and pedagogy that calls for intellectual competence (not necessarily command) in a variety of fields in order to better address specific, real-world environmental problems. In essence, systems literacy combines the study of social history and cultural discourses with a technical understanding of ecosystem processes.” (pp.4-5).

Sweeney (2012) was one of the pioneers to cultivate the notion of systems literacy in educational context. She described systems literacy as ‘level of knowledge about complex interrelationship’ (p.4). In terms of characteristics of systems literacy, she outlined that systems literate individuals are able to see multiple causes in occurrence of an event as well as grasp the importance of sharing commons such as water, air, land. Contrary to some experts, as she reported, she claimed that many children have innate ability to see systems behavior without having formal training to learn how to do it. Moreover, Sweeney added that cultivating and developing systems literacy is relatively simple since contexts in daily life lend itself to achieve this.



In short, emergence of the term, system, have brought new areas out such as system theories, systems science, systems thinking, and lastly systems literacy. Among the definitions of systems literacy, only Wood (2011) included the context of social history and cultural discourse. The other definitions emphasized cognitive processes of individuals. However, as Stables and Bishop (2001) strongly argued, the definitions of literacy contexts are operational and most of them were not constructed by considering the important arguments in general literary studies. Hence, they may lack of philosophy or theoretical framework which may result in having difficulties to proceed in the area. For these reasons, the researcher of this study regarded these critiques and intended to offer an alternative definition for systems literacy by including a general literary framework.

### **1.2. Milestones of Globalization, Education, and Systems Literacy**

To unveil the need for systems literacy, it might be useful to examine the milestones in human history especially after Industrial Revolution within which science and technology plays a key role. While milestones have both positive and negative effects on the development of political, economic, social aspects (Al-Rodhan & Stoudmann, 2006), they are also resulting in new insights on science education (DeBoer, 2000) and on the other disciplines in education as well (e.g. Merriman & Nicoletti, 2007; Orr, 2004). These milestones will be elaborated in the next chapter. Furthermore, the negative impacts of the milestones on the environment (Alagiri & Kumar, 2012; Al-Rodhan & Stoudmann, 2006) are also being one of the essential elements shaping educational agenda (Orr, 2004; Tilbury, 1995; United Nations, 1992).

Today, students are raised in a reductionist approach in which they specialize in a monolithic discipline rather than seeing interactions and complications among them (Strachan, 2009). However, the entire planet is a system and there are cycles to provide maintenance for this system. Yet, even though the context of science education and literacy contexts are partly compatible to help individuals grasp the context of these systems and cycles, we are still experiencing 21st century global issues. Correspondingly, when the contentions on the purpose of education (DeBoer, 2000;

Dewey, 1934; Dillon, 2009; Hungerford & Volk, 1990), effects of milestones on the environment, economy, society, and development (Al-Rodhan & Stoudmann, 2006), the context of existing context-based literacy definitions (McBeth et al., 2006; Mun et al., 2015; Parkin et al., 2004), 21<sup>st</sup> century global issues (Pouloupoulos, 2016; Rieuwert, 2015; Wilson & Stevenson, 2016), and the perspective of systems science and systems thinking (Ben-Zvi Assaraf & Orion, 2005a; Mobus & Kalton, 2015) are contemplated in a holistic manner, it can be concluded that we need individuals who are able to comprehend the world in which they live as a system and provide long-term solutions for 21st century global issues.

Depletion of resources and anthropogenic pollution issues accompanied with human population growth, overconsumption habits, and major environmental disasters became some of the driving forces for human beings for launching several initiatives to combat and/or minimize the detrimental effects of pollution and degradation (Alagiri & Kumar, 2012). These endeavors also induced to co-evolution of education and context-based literacies both in explicit and implicit manner. While long-term solutions are being sought, the education system is seen as a critical component to prevent or slowdown these disruptions. However, present education systems tended to disintegrate the systems and tried to explore these systems by investigating the segments of the system (Orr, 2004). The components have interactions with each other and therefore some of their properties of systems could be lost when it is tried to break down (Capra, 1996). Accordingly, hegemonic state of reductionism may hinder achieving this aim. Ison and Shelley (2016) emphasized that cultivating systems literacy and systems thinking are not on educational agenda which might be a limitation to achieve systems-literate individuals. Hence, we, educators and social scientists, should shift the focal point of education from disintegrated segments to a holistic manner. At this point, providing an alternative definition for systems literacy can be a starting point.

### **1.3. Purposes of the Study and Research Questions**

Ison (2008) reported that everyone has systemic awareness as a common sense, but the puzzled part is how educators may conceive and promote that awareness? Since our students are not educated from a systems literacy perspective and may not be familiar with the term 'system', it might not be suitable to conduct an explicit study on systems and systems literacy. Besides, an explicit study whose aim is to understand students' conceptions on systems may be too general since every system has its own dynamics (Schaefer, 1989). For these reasons, an implicit study was designed within the context of a water system in which students are actively involved in (Ben-Zvi Assaraf et al., 2012) and were taught water-related concepts from elementary grades onward (Shepardson et al., 2009).

Correspondingly, the purposes of this study are determined as to (1) provide a conceptual model for the description of 'systems literacy'; (2) propose an alternative framework for the elements of systems literacy in water system context; (3) explore possible factors that might interfere with systems literacy in water system context; and (4) determine readiness of children completing middle school degree in terms of systems literacy in water system context. Compatible with the purposes of the study, the research questions were constructed as following:

- 1) What is systems literacy?
  - a. What are the elements of systems literacy?
- 2) What is the alternative framework of systems literacy in water system context for students completing middle school degree?
  - a. What are the characteristics of the functional systems literacy in water system context for students completing middle school degree?
  - b. What are the characteristics of the cultural systems literacy in water system context for students completing middle school degree?
  - c. What are the characteristics of the critical systems literacy in water system context for students completing middle school degree?

- d. What are the interaction patterns of the elements of systems literacy in water system context for students completing middle school degreeSi?
- 3) What are the readiness levels of students completing middle school degree in terms of systems literacy in water system context?
  - a. What are the readiness levels of children completing middle school degree in terms of functional systems literacy in water system context?
  - b. What are the readiness levels of children completing middle school degree in terms of cultural systems literacy in water system context?
  - c. What are the readiness levels of children completing middle school degree in terms of critical systems literacy in water system context?
  - d. How does children's alternative conceptions interact with readiness levels of systems literacy in water context?
- 4) What are the possible factors that might interfere with systems literacy in water context for students completing middle school degree?
  - a. How does systems literacy change by means of gender, level of achievement, residence area, parental occupation, types of high school?
  - b. What are the other factors that shaped systems literacy of middle school students in water context?

#### **1.4. Significance of the Study**

The entire universe is a system and there are numerous subsystems which could be also named as systems (Mobus & Kalton, 2015). However, the current state of science education involves disintegrating the systems and exploring them by investigating their segments (Colucci-Gray, 2019; Orr, 2004). The components of a system have interactions with each other; therefore, there might be some loss of properties when systems break down into its elements (Capra, 1996). As a result, students raising in a reductionist approach might not be able to see those interactions and complications within systems (Strachan, 2009) because it requires an understanding of systems in terms of the working principles as well as probable behavior(s) in the case of failure in a system. On the other hand, systems theory and systems science provides many useful implications for scientific disciplines such as physics, biology, ecology and it

is started to be integrated into these disciplines (Mobus & Kalton, 2015). Accordingly, calibrating science education with systems and system science perspectives could provide an opportunity to raise systems-literate individuals to meet all the demands of 21<sup>st</sup> century issues. There are calls in the literature (e.g., Dubberly, 2015; Tuddenham, 2017) for developing and contributing to the systems literacy studies. At this point, redefining systems literacy within the context of science education and exploring the current state of students' systems literacy could have a potential to contribute to the literature from educational perspective. Thus, this study could provide an insight to researchers, educators, and policy makers on how to revise our current science education agenda based on students' readiness within the context of the systems literacy.

Systems science engages "... the real and necessary intersection of natural science, social science, and the humanities, areas that have traditionally been separated as discrete academic disciplines... These come together most urgently in the emergence of sustainability as the major question and challenge of the twenty-first century." (Mobus & Kalton, 2015, p.10). Therefore, we need individuals who are able to understand the world in which they live as a system and provide long-term mitigation and adaptation plans for 21<sup>st</sup> century issues. Along with the science education, education for sustainable development could be also considered as one of the approaches aiming to enable learners to obtain necessary knowledge, skills, attitudes and values to contribute to a sustainable future (UNESCO, 2015) as well as grasping the nature of 21<sup>st</sup> century issues. What is more, ESD inherently includes sustainability literacy (Nolet, 2009) and systems thinking (Sterling, 2003) in its context. Thus, the findings of the study have potential to contribute to ESD studies. Tailoring systems literacy to ESD practices could provide another standpoint to the notion of sustainable development.

Water system was chosen as a context for exploring systems literacy within the context of the study due to several reasons. First, water place in multiple elementary courses such as elementary science, social science, and even mathematics (for further information, please examine the national elementary textbooks in MoNE, 2020). All

textbooks of these courses include the concept of water. On the other hand, as Forbes et al. (2015) denoted, water is one of the essential concepts in K-12 science curriculum in which students are expected to grasp the basics of hydrology. In our national context, elementary science curriculum cover water-related concepts from 3<sup>rd</sup> to 8<sup>th</sup> grade (MoNE, 2020). In the 3<sup>rd</sup> grade level, they learn that water is a non-living thing. As the grade level increases, the importance of efficient use of water, wastewater management, groundwater and surface water, phases of water, water pollution, water cycle and weather and climate are involved (MoNE, 2018). After completing these concepts, students are expected to have an understanding on these concepts. Nevertheless, current science education in Turkish context have not accommodated yet the contexts of systems thinking and systems literacy. Additionally, revised edition of national science curriculum includes the notion of ESD (MoNE, 2018) and both explicit and implicit objectives are present within the water chapters of the textbooks. Hence, Turkish middle school students are expected to have an understanding of water within the context of science education and ESD when they complete middle school degree. These characteristics makes water system a suitable context to be studied readiness for systems literacy.

Second, water is an important concept because it provides basis for understanding of weather and climate (Sadler, Nguyen, & Lankford, 2017), the complexity of life and interconnectedness of the earth systems (Brody, 1993), and effects of water use on the environment (Österlind & Haldén, 2007), economy (Wood, 2014; DeLorme, Hagen, & Stout, 2003), and society (Wood, 2014). However, from the beginning of the integration of water into educational context in 1960s (Ewing & Mills, 1994), studies consistently revealed that students developed a rudimentary understanding for water and water-related concepts (Ben-Zvi-Assaraf & Orion, 2005a; Covitt, Gunckel, & Anderson, 2009). Thus, exploring students' systems literacy in water context might contribute to the literature on how middle school students construct their mental models on water system and its interactions with the other systems including human systems.

Third, according to the report of UNESCO (2015), present status of water education in most countries is insufficient since conventional teaching approaches focuses on students' level of achievement. As Schaap and van Steenberg (2001) claimed, water issues should also be addressed by considering attitudes, skills, and behaviors in schools in addition to level of knowledge so that students could be able to grasp their local and regional water issues by transferring their theoretical background to their daily life. At this point, selecting water system to explore students' systems literacy could contribute to addressing those constructs given above because students probably had already conceptions on water, water cycle, and the effects of human beings on local/global water system, attitudes towards water use, and individuals' water consumption patterns. Examining their readiness in water system context might pave the way for revising water education status so as to integrate additional constructs in addition to level of knowledge.

In addition to determining the readiness of systems literacy in the water system context, determining possible factors that might interfere with this type of systems literacy could promote understanding on the nature of the systems literacy as well as systems literacy in water system context. Some of the elements within the systems literacy in water context have already been reported as interacted with some factors such as cognitive differences (Ben-Zvi-Assaraf & Orion, 2005a), role of media (Wood, 2014), parents (Aarø et al., 2009) as well as daily life experiences (Havu-Nuutinen, Kärkkäinen & Keinonen, 2018). Thus, including these factors within the context of this study and exploring whether these potential factors might interfere with systems literacy or not could be an integral element to comprehend infrastructure of systems literacy in water system context.

The target of the study was chosen 9<sup>th</sup> grade students since choosing 9<sup>th</sup> grade students may provide us an insight about how our middle school curriculum shapes our students' systems literacy in water context. As water system is disintegrated into separate concepts in curricula except water cycle (Sadler, Nguyen, & Lankford, 2017), this also enable us to see how reductionist approach contribute to the students' systems literacy in water context. In the long run, this study may guide researchers and

curriculum developers about *statu quo* of the middle school students' level of systems literacy.

To recap, educating individuals from systems science perspective could contribute to improve them to deal with 21<sup>st</sup> century issues (Mobus & Kalton, 2015). At this point, researchers of this study believed systems science perspective can be integrated into science education as well as into ESD. In this context, defining systems literacy and determine middle school students' readiness for being systems-literature can be an initial point. Based on all these reasons summarized above, the researcher intended to offer a theoretical framework for systems literacy that can be used both in science education and ESD.

### **1.5. Context of the Study**

The participants of this study were chosen as 9<sup>th</sup> grade students who are recently completed their middle school degree. There are public and private high schools in Turkey and the processes of registration are different from each other. The students are registered public high schools in two ways. Some public high schools accept students according to their high school entrance exam scores, whereas others accept students based on their residence addresses (Ministry of National Education, 2018). On the other hand, private high schools' registrations have various requirements specific to the schools. There are different types of public high schools in Turkey such as Science High School, Social Sciences High School, Anatolian High School, Vocational and Technical Anatolian High School, Multi-Program Anatolian High School, Anatolian Religious High School, Sports High School, Fine Arts Anatolian High School, Correspondence High School, and Vocational and Technical Training Centers (Ministry of National Education, 2017). Among the private high schools, there are also some types of high school such as Science Private High Schools and Anatolian Private High School.

During the first semester of 9<sup>th</sup> grade level, high school curricula do not include specific chapters devoted to the water but some minor conceptions on water such as (1) the rate of water in living organisms and importance of water in human body in



biology course, (2) the properties of water as evaporative cooling, adhesion, cohesion, water as a universal solvent and water as a polar molecule in chemistry course, and (3) listing hydrosphere as one of the Earth's spheres in geography class (Turkish Education Board, 2019).

## 1.6. Organization of the Chapters

As this dissertation is constructed based on a research cycle composed of conceptual research, empirical research, and their interactions, some of the chapters are specific to the particular research, whereas the remainder of the chapters include them both. Chapter 2 provides a critical literature review on the need for systems literacy. This chapter includes several context-based literacies that contain the notions of system, system science, and systems thinking. Chapter 2 also provide a basis for suggesting a conceptual model for the description of 'systems literacy' (*Research Question 1*) and propose an alternative framework for the elements of systems literacy in water system context (*Research Question 2*). On the other hand, chapter 3 involves a review of literature on water studies in K-12 education. Chapter 4 is about the methodologies that are employed within the context of the research cycle of this study. Chapter 5 presents findings retrieved from both conceptual and empirical research. Last, chapter 6 provides discussions, conclusions and implications based on the findings of the study as well as previous studies in the literature. Table 1.1 summarized the organization of the chapters.

**Table 1-1**

*Organization of the Chapters*

| <b>Chapter</b>                                                            | <b>Content</b>                  |
|---------------------------------------------------------------------------|---------------------------------|
| Chapter 2 – A Critical Literature Review on the Need for Systems Literacy | Conceptual Research             |
| Chapter 3 – Review of Literature on Water Studies on K-12 Students        | Empirical Research              |
| Chapter 4 – Methodology                                                   | Conceptual & Empirical Research |
| Chapter 5 – Findings                                                      | Conceptual & Empirical Research |
| Chapter 6 – Discussions, Conclusions & Implications                       | Conceptual & Empirical Research |

## CHAPTER 2

### A CRITICAL LITERATURE REVIEW ON THE NEED FOR SYSTEMS LITERACY

*“Literacy is a bridge from misery to hope”*

*Kofi Annan (1997)*

In this chapter, the need for systems literacy was elaborated by reviewing context-based literacies that includes the notion of systems and systems thinking were selected to be reviewed. Accordingly, a brief literature reviews on scientific literacy, environmental literacy, sustainability literacy, and systems thinking studies in educational context were provided. Then, the need for systems literacy was argued and previous studies related to systems literacy were presented to provide an insight for philosophical conceptualization for an alternative description for systems literacy.

#### 2.1 The Salience of Scientific Literacy

As in the other disciplines in education, the purpose and outcomes are being debated in science education as well (e.g., Coll & Taylor, 2012; DeBoer, 2000). However, this has been attracting more attention than others among the countries since there is a common sense that the level of development is affected by scientific and technological progress (Coll & Taylor, 2012; Laugksch, 2000) and correspondingly, countries have been investing tremendous effort and money to their science education policies. For instance, National Education Association (NEA) published two reports in 1918 and in 1920 to manifest the role of education as preparing individuals to be effective for their community. In particular, the importance of science education was emphasized in these reports as “the application of [scientific] knowledge to the activities of life, rather than primarily in terms of the demands of any subject as a logically organized science” (NEA, 1918, p. 8). Correspondingly, science curriculum was reconstructed to meet

this particular purpose. By 1932, the discussions on the purpose of science education went further in a way that science education became too subject-matter oriented and the main reason of science teaching discarded which was to offer an extensive understanding of the natural world and its relationships with human life (DeBoer, 2000). Until the late 50's, the contentions on the purpose and the context of science education led to curriculum reforms and these reforms, in turn, provided new arguments on the question "What is science education for?"

Similar with the other contexts in education, literacy was emerged as one of the most frequently used terms within the debates on the purpose of science education (DeBoer, 2000; Dillon, 2009; Wang & Schmidt, 2001). Scientific literacy or science literacy firstly pronounced in the late 50s; however, the literature on scientific literacy accelerated in the last 30 years (Roberts, 2007b). At the initial stage, the term was used by Hurd (1958) and in Rockefeller Report (1958) with no definition. Howard Meyerhoff, chairman of the geology department at the University of Pennsylvania, made one of the earliest definition as "familiarity with scientific methods and... sufficient knowledge in the several fields of science to understand reports of new discoveries and advances" (as cited in Carlton, 1963, p. 34). Since then, many definitions for scientific literacy and its components as well are being suggested (DeBoer; 2000; Robert, 2007b) and no universal definition was accepted. Some of these definitions and their components were summarized in [Table 2-1](#).

As noted earlier in this chapter, the cruise of seeking the purpose of education brought many puzzled answers and those, which are related to science education, became one of the hallmarks among them. The aim of science education has been constantly argued and increasing the level of scientific literacy was highlighted most. As summarized in [Table 2-1](#), different perspectives about definition and components of scientific literacy were being given. Although it seems that there are many definitions, all these descriptions were clustered as Roberts (2007b) did in the Handbook of Science Education. When the chronological order was traced, it can be observed that definitions within *Vision I* were made at the earlier stages, whereas definitions within *Vision II* came to the agenda in the past 30 years.

**Table 2-1***Chronological Order of Definition of Scientific Literacy*

| <b>Reference</b>                     | <b>Definition of Scientific Literacy</b>                                                                                                                                                                                                                                                                                                                                                                             | <b>Components of Scientific Literacy</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| National Science Education Standards | “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity.” (National Research Council, 1996, p. 22).                                                                                                                                                               | <p>Five main assumptions justified the identification of the content standards:</p> <p>(a) utilize scientific evidence to decide in daily life activities.</p> <p>(b) participate perceptively in civic discourse and argue about significant issues that contain science and technology.</p> <p>(c) feel eagerness and have self-satisfaction due to comprehending about the earth mechanisms.</p> <p>(d) enable to improve individuals to grasp, inquire, deliberate, enact, and develop response(s) to the problems so that they could be able to have necessary skills for future careers</p> <p>(e) U.S should raise equally proficient individuals to accommodate in international markets</p> |
| Roberts (2007b)                      | <p><i>Vision I</i>: “looks inward at science itself – its products such as laws and theories, its processes such as hypothesizing and experimenting (literacy within science)” (Roberts, 2007b, p.9)</p> <p><i>Vision II</i>: “looks outward at situations in which science has a role, such as decision-making about socio-scientific issues (literacy about science-related situations)” (Roberts, 2007b, p.9)</p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

Table 2.1 cont.'d

| Reference                                                                              | Definition of Scientific Literacy                                                                                                                                                                                                                                                                                                                                                                                                                          | Components of Scientific Literacy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Twenty First Century Science (2008)                                                    | No explicit definition                                                                                                                                                                                                                                                                                                                                                                                                                                     | <ul style="list-style-type: none"> <li>• appreciate and understand the impact of science and technology on everyday life;</li> <li>• take informed personal decisions about things that involve science, such as health, diet, use of energy resources;</li> <li>• read and understand the essential points of media reports about matters that involve science;</li> <li>• reflect critically on the information included in, and (often more important) omitted from, such reports; and</li> <li>• take part confidently in discussions with others about issues involving science. (as cited in Dillon 2009, p.206)</li> </ul> |
| Curriculum Development Council and The Hong Kong Examinations and Assessment Authority | <p>The overarching aim of the curriculum is to nurture students' scientific literacy so that they develop 'thinking tools' for reflecting on science, see the coherence among seemingly diverse sets of ideas, and discover unifying concepts (such as systems, order and organization) that pervade science and transcend disciplinary boundaries. (Curriculum Development Council and The Hong Kong Examinations and Assessment Authority 2015, p.8)</p> | <ul style="list-style-type: none"> <li>- <i>Knowledge and Understanding</i></li> <li>- <i>Skills and Processes</i> <ol style="list-style-type: none"> <li>1- Scientific Thinking</li> <li>2- Scientific Investigation</li> <li>3- Practical Skills</li> <li>4- Problem-solving</li> <li>5- Information Handling</li> <li>6- Informed Decision-making</li> <li>7- Independent Learning</li> <li>8- Communication Skills</li> <li>9- Collaboration</li> </ol> </li> <li>- <i>Positive Values and Attitudes</i></li> </ul>                                                                                                           |

Table 2.1 cont.'d

| Reference         | Definition of Scientific Literacy                                                                                                                                                                                                                                            | Components of Scientific Literacy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PISA 2018         | “Scientific Literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology” (OECD, 2019, p.100) | <ul style="list-style-type: none"> <li>- <i>Contexts</i> <ol style="list-style-type: none"> <li>1- Personal</li> <li>2- Local/ National</li> <li>3- Global</li> </ol> </li> <li>- <i>Knowledge</i> <ul style="list-style-type: none"> <li>Content Knowledge</li> <li>Procedural Knowledge</li> <li>Epistemic Knowledge</li> </ul> </li> <li>- <i>Competencies</i> <ol style="list-style-type: none"> <li>1- Explain phenomena scientifically</li> <li>2- Evaluate and design scientific enquiry</li> <li>3- Interpret data and evidence scientifically (OECD, 2019, p.102)</li> </ol> </li> </ul>                                                                                                                                                                             |
| Mun et al. (2015) | No explicit definition                                                                                                                                                                                                                                                       | <ul style="list-style-type: none"> <li><i>Content Knowledge</i> <ol style="list-style-type: none"> <li>1- Core ideas</li> </ol> </li> <li><i>Habits of Mind</i> <ol style="list-style-type: none"> <li>1- Collaboration</li> <li>2- Systematic Thinking</li> <li>3- Non-Routine Problem-Solving</li> <li>4- The Use of Evidence to Support Claims</li> <li>5- The Development of Models</li> <li>6- Information Management</li> </ol> </li> <li><i>Character and Values</i> <ol style="list-style-type: none"> <li>1- ecological worldview</li> <li>2- moral and ethical sensitivity</li> <li>3- socio-scientific accountability</li> </ol> </li> <li><i>Science as Human Endeavor</i></li> <li><i>Metacognition and self-direction</i> (Mun et al., 2015, p.1750)</li> </ul> |

Besides, some studies like those that Mun et al. (2015) did may not be considered neither of the two visions due to nature of their studies. In brief, either in the two visions or in the other studies, the definition of scientific literacy evolved in time to encompass some other issues in which science has a role. What is more, as Pedretti (2014) highlighted, two contexts in science education were emerged as science, technology, society and environment (STSE) education (Pedretti & Nazır, 2011; Solomon & Aikenhead, 1994) and socioscientific issues (SSI) (Zeidler et al, 2009). Correspondingly, these two contexts also re-directed both the aim of science education and the definition of scientific literacy (mostly *Vision II*).

## **2.2 Ripple Effect of the Milestones of Globalization on Science Education**

Science education and scientific literacy are always subject to be re-conceptualized in time. In order to find the reasons for this co-evolution, it might be useful to examine the milestones in human history within which science and technology plays a key role. While milestones have both positive and negative effects on the development of political, economic, social aspects (Al-Rodhan & Stoudmann, 2006), they are also resulting in new insights on science education (DeBoer, 2000) and on the other disciplines in education (e.g., Merriman & Nicoletti, 2007; Orr, 2004; United Nations, 1992). Furthermore, the negative impacts of the milestones on the environment (Alagiri & Kumar, 2012; Al-Rodhan & Stoudmann, 2006) are also one of the essential elements shaping educational agenda (Orr, 2004).

Even though human beings are not very good at living in harmony with their environment from prehistoric times to the present, the negative effects of human activities on the environment intensified particularly after Industrial Revolution (Poulopoulos, 2016; Rieuwerts, 2015) when developmental activities escalated. To illustrate, some of milestones could be listed as (1) invention of the steam engine in 1765 (Al-Rodhan & Stoudmann, 2006), (2) competition in basic goods -wheat and textiles- in early 1800's (Al-Rodhan & Stoudmann, 2006), (3) World War II (Rennen & Martens, 2003), (4) The Manhattan Project between 1942-1946 (Al-Rodhan & Stoudmann, 2006), (5) invention of digital computer (Scholte, 1999), (6) opening of

First McDonald's Restaurant in 1955 (Al-Rodhan & Stoudmann, 2006; Scholte, 1999), and (7) introduction of World Wide Web in 1991 (Al-Rodhan & Stoudmann, 2006). On the other hand, as Rieuwerts (2015) noted, the effects of human activities on the environment can be grouped into two general sets as 'resource depletion' and 'pollution'. Whereas he relates resource depletion to "...energy choices, food and water scarcity, natural landscape damage and biodiversity loss..." (p. xix), he explained anthropogenic pollution as "...implies that environmental harm will, or might, be caused by contamination. Furthermore, pollution is typically (although not always) associated with human activity; for example, significant quantities of polluting substances are lost to the environment during the extraction and processing of raw materials and the manufacture, use and disposal of final products" (p.1). When milestones and definitions given above are examined together, it can be inferred that milestones both contribute to resource depletion and anthropogenic pollution.

These unsustainable resource depletion and anthropogenic pollution issues accompanied with human population growth, overconsumption habits, and major environmental disasters such as Great Smog of London in 1952, Minamata "disease" in Japan 1956, Bhopal disasters in India in 1984, Chernobyl nuclear disaster in Ukraine 1986, and Gulf War oil spill in 1991 became some of the driving forces for human beings to consider the effects of these milestones listed above. Correspondingly, several initiatives were launched to combat and/or minimize the detrimental effects of pollution and degradation (Alagiri & Kumar, 2012). For instance, publication of *Silent Spring* in 1962, the foundation of OECD Environment Committee in 1970 (Alagiri & Kumar, 2012), the foundation of Greenpeace in 1971 (Al-Rodhan & Stoudmann, 2006), the publication of *Limits to Growth* in 1972 (Scholte, 1999), Stockholm Conference on Human and Environment in 1972 (Alagiri & Kumar, 2012), Montreal Protocol on Ozone Layer Protection in 1987 (Alagiri & Kumar, 2012), Bruntland Report: Our Common Future in 1987, Earth Summit in 1992, Kyoto Protocol for reducing greenhouse gas emissions in 1997 and 2005 (Alagiri & Kumar, 2012) are some of the other milestones that intend to protect the environment and minimize our impact on the planet. These endeavors are also addressed some changes in education both in explicit and implicit manner.



The ripple effect of all of these milestones given above induced to co-evolution of science education and scientific literacy. As Meadows, Meadows, Randers and Behrens (1972) denoted in *Limits to Growth*, the natural reserves on Earth is limited and human beings used them in unsustainable way for industrialization, economic growth and food production etc. Therefore, scientific literacy has become an essential element that needs to be revised to meet these demands of the 21<sup>st</sup> century (Choi et al. 2011) and to promote *sustainability* (Carter, 2008). Nevertheless, although the definitions within Vision II emphasize “looks outward at situations in which science has a role”, it is still science-dominated, and today’s global issues have more elements than science and technology. Hence, we should look for a broader definition of literacy where science and technology are two of the essential components, but not the umbrella concept. What is more, the components of scientific literacy, in general, do not include “*behavior change*” which is also one of the other frequently used concepts within the context of the purpose of education.

### **2.3 Another Branch of Phylogenetic Tree of Literacy: Environmental Literacy**

The impacts of milestones give rise not only the evolution of scientific literacy but also some other context-based literacies (e.g., Nolet, 2009; Orr, 1994; Roth, 1984) in time. Among them, *environmental literacy* (EL) can be considered as a comprehensive concept both overlapping with scientific literacy (Roth, 1992) and including milestones discussed above. Besides, EL embraces the dimension *behavior*, which was not covered explicitly by scientific literacy.

Even though environmental education introduced in mid 1960s (as cited by Roth, 1992), the vocabulary of *environmental literacy* was firstly introduced by Roth in 1968. Not surprisingly, its description is being subject to some changes and improvements (Roth, 1992; Marchinkovski et al., 2013) as in the other literacy definitions. In addition, raising environmentally literate individuals turned out to be one of the primary goals of environmental education (Carter & Simmons, 2010; Roth, 1992). One of the earliest definitions was made by Hungerford and Tomara in 1977 (as cited by Roth, 1992, p.20) “development of an environmentally literate citizenry,

i.e., a citizenry that is both competent to take action on critical environmental issues and willing to take that action." Since then, a lot of studies are being conducted for constructing environmental literacy framework, the present state of their individuals as environmentally literate, and correspondingly the results of these studies are being used for practices (e.g., Fleming, 2009; McBeth et al., 2008). All of these studies were conducted under the EE goals and objectives published by UNESCO (1978) by addressing the components such as *knowledge*, *cognitive skill*, *affective disposition*, and *behavior* (e.g., Hungerford & Volk, 1990; Roth, 1992; Simmons, 1995; Wilke, 1995). Especially after 1995, these studies have been conducting in more systematic approach to assess environmental literacy by developing appropriate instruments (Marcinkowski et al., 2013), and administered as nationwide in different countries (e.g., McBeth et al., 2008; Negev et al., 2008; Shin et al., 2005) as well as international studies (OECD, 2006). Some of them was listed in [Table 2-2](#) and [Table 2-3](#).

Even though there are different definitions and components of environmental literacy as summarized in [Table 2-2](#) and [Table 2-3](#), they have much more in common. For instance, almost of the descriptions involved the dimension of *skills* both in explicit and implicit manner. Some descriptions refer skills in a general sense (McLaren, 1989; UNESCO-UNEP, 1989), whereas some others include skills in a specific manner such as cognitive skills (McBeth et al., 2008; Negev et al., 2008), problem solving (UNESCO-UNEP, 1989), critical thinking (McClaren, 1989), and Roth (1992) specified many useful skills in every level of his definition for environmental literacy. In a similar context, *knowledge*, *affect*, and *behavior* are also frequently used as components of environmental literacy. On the other hand, when Chapter 31 of *International Handbook of Research on Environmental Education* was examined, the differences between national assessments were given in a clear picture in this chapter. For example, every country has different in number of components for EL. As Marcinkowski et al. (2013) noted, while all four countries included environmental knowledge (except for U.S.A) and ecological knowledge, environmental sensitivity, and verbal commitment /willingness as components of EL, locus of control and personal responsibility were only examined by Korea and Israel.

**Table 2-2***Earlier Definitions of Environmental Literacy*

| Reference          | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Roth<br>(1984)     | <p>“Produce a citizenry that:</p> <ol style="list-style-type: none"> <li>Understands the self-regulating systems of our life-sustaining planet.</li> <li>Operate their lifestyles in congruence with those self-regulating systems.</li> <li>Work cooperatively to eliminate cultural activities that significantly disrupt the life-sustaining systems”. (as cited in Roth, 1992, p.21)</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| McClaren<br>(1989) | <ol style="list-style-type: none"> <li>The ability to think about systems.</li> <li>The ability to think in time: to forecast, to think ahead, and to plan.</li> <li>The ability to think critically about value issues.</li> <li>The ability to separate number, quantity, quality, and value.</li> <li>The ability to distinguish between the map and the territory.</li> <li>The capacity to move from awareness to knowledge and action.</li> <li>A basic set of concepts and facts; the ability to learn new ones and unlearn the old.</li> <li>The ability to work cooperatively with other people.</li> <li>The capacity to use skills in eight processes: knowing, inquiring, acting, judging, opening, imagining, connecting, and valuing. (as cited in Roth 1992, p.22)</li> </ol>                                                                                                                                                                                                                                                              |
| Roth<br>(1992)     | <p>“<i>Nominal environmental literacy</i> specifies a person able to recognize many of the basic terms used in communicating about the environment and able to provide a rough, if unsophisticated, working definition of their meaning”. (Roth,1992, p.28)</p> <p>“<i>Functional environmental literacy</i> indicates a person with a broader knowledge and understanding of the nature and interactions between human social systems and other natural systems””. (Roth,1992, p.29)</p> <p><i>Operational literacy</i> indicates a person who has moved beyond functional literacy in both the breadth and depth of understandings and skills and routinely evaluates the impacts and consequences of actions; gathering and synthesizing pertinent information, choosing among alternatives, and advocating action positions and taking actions that work to sustain or enhance a healthy environment” (Roth,1992, p.32)</p> <p>(Each level has 4 major strands (Knowledge, Affect, Skill, and Behavior) and different qualifications within them)</p> |

**Table 2-3***Recent Components of Environmental Literacy*

| Reference                     | Components of Environmental Literacy                                                                                                                                                                                                                                                                                                                                                 | Reference                  | Components of Environmental Literacy                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Shin, Chu et al. (2005) Korea | <p><i>I. Knowledge</i><br/>Ecological Knowledge<br/>Environmental Knowledge</p> <p><i>II. Affect</i><br/>Environmental Sensitivity<br/>Environmental Attitudes<br/>Personal Responsibility<br/>Locus of Control / Efficacy<br/>Verbal Commitment / Willingness</p> <p><i>III. Cognitive Skills</i></p> <p><i>IV. Behavior</i><br/>(as cited in Marcionkowski et al. 2013, p.326)</p> | Erdogan (2009) Turkey      | <p><i>I. Knowledge</i><br/>a. Ecological Knowledge<br/>b. Environmental Knowledge</p> <p><i>II. Affect</i><br/>c. Environmental Sensitivity<br/>d. Environmental Attitudes<br/>e. Verbal Commitment / Willingness</p> <p><i>III. Cognitive Skills</i></p> <p><i>IV. Behavior</i><br/>(as cited in Marcionkowski et al. 2013, p.326)</p>                                |
| McBeth et al. (2005) USA      | <p><i>Knowledge</i><br/>Ecological Knowledge</p> <p><i>II. Affect</i><br/>Environmental Sensitivity<br/>Environmental Feelings<br/>Verbal Commitment / Willingness</p> <p><i>III. Cognitive Skills</i></p> <p><i>IV. Behavior</i><br/>(as cited in Marcionkowski et al. 2013, p.326)</p>                                                                                             | Negev et al. (2008) Israel | <p><i>I. Knowledge</i><br/>a. Ecological Knowledge<br/>b. Environmental Knowledge</p> <p><i>II. Affect</i><br/>c. Environmental Sensitivity<br/>d. Environmental Attitudes<br/>e. Personal Responsibility<br/>f. Locus of Control / Efficacy<br/>g. Verbal Commitment / Willingness</p> <p><i>III. Behavior</i><br/>(as cited in Marcionkowski et al. 2013, p.326)</p> |

Although environmental literacy could be regarded as more comprehensive context-based literacy than scientific literacy (Roth, 1992), there may be still some missing points when the purpose of education and the effects of milestones were considered together. For instance, some of the components such as *knowledge* and *affect* emphasized mainly the context of environment and ecology. However, as stated in the former sections, milestones affect the development of policies, economy, and society both positively and negatively (Al-Rodhan & Stoudmann, 2006) as well as the environment and they are also resulting in new insights in education (Merriman &

Nicoletti, 2007). What is more, recent global issues like exceeding carrying capacity of the planet (WWF; 2006), overpopulation (Raven & Berg, 2006), and climate change (Wilson & Stevenson, 2016) etc. are unsustainable, interconnected and complex problems that require to be solved by more than one stakeholder (Harris & Lyon, 2014). Thus, solutions for these unsustainable patterns with the help of technology have been creating other problems in today's world like a chain reaction.

#### **2.4 One Step Further: Sustainability Literacy**

Environmental literacy is a comprehensive concept overlapping with scientific literacy (Roth, 1992); integrating the effects of milestones on its framework; and embraces the dimension *behavior*. However, when the components/themes of environmental literacy, milestones and global issues in today's world were examined holistically, it can be inferred that their interactions and effects have much more elements than science, technology, and environment such as economy, policy, and society. Therefore, we might need to expand the context of EL so as to meet postmodern society's need as cited in *Limits to Growth*.

Sustainable development (SD) can be considered as one of the paradigms that cover these concerns discussed above. In this paradigm, economy and society are also as important as environment (Harrington, 2013) and science is an element but not an umbrella concept. The definition of SD was firstly introduced in World Commission on Environment and Development report as (1987, p.4) "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". As McKeown (2006) highlighted, SD is a paradigm that consider the equilibrium among environment, economy, and society to maintain development and quality of life. In order to achieve this equilibrium, education is seen as an essential and complementary element of sustainability (Onwueme & Borasi, 2007). Correspondingly, this paradigm was integrated into education known as *education for sustainable development* (ESD). ESD was introduced at *United Nations Conference on Environment & Development, Agenda 21* in 1992. The dimensions of SD were included into the notion of ESD as environment,

economy, and society (McKeown, 2002). On the other hand, the content of ESD was determined so as to enable learners to obtain necessary knowledge, skills, attitudes and values to contribute to a sustainable future (UNESCO, 2015). Along with UN, many researchers, educators, NGOs, and other stakeholders around the world are contributing to improve the context of ESD and to help permeate ESD into educational systems of the countries.

As the notion of ESD continues evolving, a need for a definition for literacy in this area was emerged as in the other educational contexts since ESD educators and researchers aim to explore how this integration affect students' understanding, level of knowledge, motivation, and behaviours toward sustainability issues (e.g. Kagawa, 2007; Biasutti & Frate, 2016). Although there is no singular definition for sustainability literacy, the main idea behind defining it is similar. The inspiration of sustainability literacy was emerged from Orr's definition of ecological literacy in 1992 (Lugg, 2007; Nolet, 2009). For example, Parkin et al.'s study (2004) described the term *sustainability literacy* as an inclusive term for the perspectives and knowledge that permit students to grasp the interdependent relationships between environmental, social and economic aspects of SD.

The context of sustainability literacy is relatively new; therefore, there is limited number of studies and descriptions in the accessible literature. Some of the definitions and components/themes were listed in Table 2-4..

**Table 2.4**

*Definitions and Themes of Sustainability Literacy*

| Reference                           | Scope / Definition                                                                                                                                                                                                                                                                                   | Components/Themes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Parkin et al., 2004)               | “Sustainability literacy encompasses ecological /environmental literacy and includes an even broader set of knowledge and skills, involving understanding the symbiotic relationships between environmental, social and economic dimensions of sustainable development” (Parkin et al., 2004, p. 9). | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| The Higher Education Academy (2006) | “A set of knowledge and skills that should be attained by ‘sustainability literate’ graduates in order to contribute to the ‘long-term future of the economy and ecology of our communities’” (The Higher Education Academy p. 2).                                                                   | <p>Appreciation of the importance of environmental, social, political and economic contexts for each discipline.</p> <p>A broad and balanced foundation knowledge of sustainable development, its key principles and the main debate within them.</p> <p>Problem-solving skills in a non-reductionist manner for highly complex real-life problems.</p> <p>Ability to think creatively and holistically and to make critical judgements.</p> <p>Ability to develop a high level of self-reflection.</p> <p>Ability to understand, evaluate and adopt values conducive to sustainability.</p> <p>Ability to bridge the gap between theory and practice</p> <p>Ability to participate creatively in inter-disciplinary teams.</p> <p>Ability to initiate and manage change (The Higher Education Academy, 2006, p. 6).</p> |

Table 2.4 cont. 'd

| Reference                          | Scope / Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Components/Themes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nolet (2009)                       | The ability and disposition to engage in thinking, problem solving, decision making, and actions associated with achieving sustainability... sustainability literacy certainly would involve knowledge, skills, and values that inform an individual's mental models and day to-day behaviours. It entails more than simply knowing things about the environment, economics, or equity and justice issues, but rather involves a willingness and ability to engage intellectually and personally with the tensions that are created by the interconnectedness of these systems (Nolet, 2009 p.421) | Stewardship<br>Respect for limits<br>Systems thinking and interdependence<br>Economic restructuring<br>Social justice and fair distributions<br>Intergenerational perspective<br>Nature as model and teacher<br>Global citizenship<br>Importance of local place<br><br>"The foregoing list of nine themes is intended to be neither a definitive nor exhaustive description of sustainability literacy. Each of the themes includes some specific knowledge or skills component, and each also clearly includes a component that likely would be characterized as disposition or belief." (Nolet 2009, p.428)                                                                                                                 |
| Warren, Archambault & Foley (2014) | They used the term literacy as, "a collection of skills that allow for effective participation and influence in diverse areas of social life" (Stibbe & Luna, 2009).                                                                                                                                                                                                                                                                                                                                                                                                                               | <i>Four ways of thinking for building sustainability literacy</i><br><br>"Futures Thinking: integrates the ability to think systematically about the future and future generations. In seeking sustainable solutions, stakeholders, policy makers, innovators, and citizens need consider how past decisions led us to the crises we face today" (Warren, Archambault & Foley, 2014, p.6)<br><br>"Values Thinking: values thinking involves concepts of justice, equity, social-ecological integrity, and ethics. It also means understanding how these concepts vary across and within cultures, and how integrating these concepts contributes to solving sustainability problems" (Warren, Archambault & Foley, 2014, p.7) |



| Table 2.4 cont.'d                               |                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------------------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reference                                       | Scope / Definition | Components/Themes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Warren, Archambault & Foley (2014)<br>(cont.'d) |                    | <p><i>Systems Thinking:</i> Systems thinking is also known as interconnected thinking or holistic thinking... Systems thinking does not claim complete knowledge. Rather, systems thinking is about assessing the degree of system complexity and analyzing system dynamics to make informed decisions that reduce the risk of negative outcomes (Warren, Archambault &amp; Foley, 2014, p.8)</p> <p><i>Strategic Thinking:</i> Strategic thinking means being able to develop a strategy or a plan to achieve a particular vision. Strategic thinking frames every decision by how it contributes to achieving that vision. It involves considering possible solutions under a given certain set of assumptions, articulating potential alternative solutions, and challenging existing assumptions and alternatives, potentially leading to new solutions that may be more appropriate (Warren, Archambault &amp; Foley, 2014, p.9)</p> |

At a first glance, from the definitions of the environmental literacy and sustainability literacy, it can be inferred that sustainability literacy is differentiated from environmental literacy's definitions in a way that sustainability literacy attaches equal importance to environment, economy, and society while the focal point of the environmental literacy is the environment itself. Nevertheless, the evolution of finding a definition for sustainability literacy is tracking a similar pattern with the environmental literacy such that sustainability literacy is defined with an emphasis on subject matter knowledge on sustainability and some skills (e.g. Winter & Cotton, 2012; Carteron et. al, 2014) until now. Moreover, no systematic studies and clear list of components were given by the researchers as in the EL studies. Instead, rich and thick descriptions were provided about how individuals become sustainable literate in different studies pertaining to ESD.

## **2.5 Looking with a Magnifying Glass to the Sustainability Literacy: Systems**

### **Thinking**

When the ripple effect of milestones, the evolution of context-based literacies summarized above, and today's global issues are examined holistically, it can be concluded that sustainability literacy may be one of the comprehensive answers that might cover the arguments on the purpose of education. It contains following:

- encompassing the elements of scientific literacy (Colucci-Gray, Barbiero, Camino, & Gray, 2006) and ecological /environmental literacy (Parkin et al., 2004)
- comprising knowledge, skills, and values that goes beyond merely knowing about the environment, economics, or equity and justice issues (Nolet, 2009)
- grasping the interdependent relationships between environment, economy and society (Parkin et al., 2004)
- including a disposition and capacity to engage mentally and individually that are shaped by the interconnectedness of the systems (Nolet 2009).

Based on these characteristics, it can be deduced that sustainability literacy has a potential to overcome limitations of other types of context-based literacies for now

that was presented in the former sections. Nevertheless, sustainability literacy is relatively new and continue evolving in its context. Therefore, it will be also subject to different alterations as time passes due to changes in global and local current needs.

Either one way or another, there is a common characteristic in different descriptions and elements of sustainability literacy that has a potential to remain, even though the context-based literacies changes/modifies in time. This element is called as *systems thinking* (e.g., Nolet, 2009; Warren, Archambault & Foley, 2014) that studied in sustainability literacy. Recent scientific literacy studies (e.g., Mun et al., 2015) study and some environmental literacy studies (e.g., McClaren 1989; Roth, 1984) included the concept of systems thinking as a component. Moreover, global issues are also required systems thinking approach to examine and overcome the reasons and the effects of them (Richmond, 1993). Besides, some other sustainability studies (e.g., Palmberg et. al, 2017; Sterling, 2003) investigated the nature of systems thinking approach and its elements since it was considered as an essential concept for sustainability. Due to these reasons, systems thinking can be considered as a promising concept to be explored in detail.

Systems thinking is accepted as one of the key competencies in sustainability (Wiek et al., 2011). Further, systems thinking skills have been attracting attention also in science education, environmental education, and education for sustainable development. Although the very first *systems thinking* approaches started in late 80's (Capra, 1996; Schaefer, 1989), its convergence to science education (e.g., Ben-Zvi Assaraf & Orion 2005a) was accelerated in 00's. What is more, National Research Council (2012) put systems thinking in within the framework of science and engineering education. Recently, Mun et al. (2015) include systems thinking as a dimension of scientific literacy. On the other hand, Roth (1992) mentioned systems thinking in an implicit manner within the definition of functional environmental literacy as "...indicates a person with a broader knowledge and understanding of the nature and interactions between human social systems and other natural systems" (p.28). In ESD, systems thinking included within the context of sustainability competencies (UNECE, 2011; Wiek et al., 2011) and sustainability literacy (Nolet,

2009; Warren, Archambault & Foley, 2014) since systems thinking enables individuals (1) to grasp and operate complex conditions (Tilbury, 1995); (2) to promote thinking the interrelationships through different social, environmental, economic, and educational components (WWF Scotland, 2010); and (3) to support grasping the reciprocal interactions and realizing that a decision lead to some unintended results of actions or/and events (UNECE 2010b).

Capra (2005) claimed that system thinking emphasize “wholes” rather than “parts”, “processes” rather than “products”, seeking patterns in systems rather than analyzing systems. Moreover, he noted that systems thinking is related to the relationships, connectedness, and the context. On the other hand, Ben-Zvi Assaraf and Orion (2005a) identified eight hierarchical characteristics for systems thinking as (p.523);

1. The ability to identify the components of a system and processes within the system
2. The ability to identify relationships among the system’s components.
3. The ability to organize the systems’ components and processes within a framework of relationships
4. The ability to make generalizations
5. The ability to identify dynamic relationships within the system
6. Understanding the hidden dimensions of the system
7. The ability to understand the cyclic nature of the systems
8. Thinking temporally

In the context of ESD, Nolan (2009) identified systems thinking as a components of sustainability literacy. In a similar manner, Karaarslan (2016) identified 12 systems thinking skills for pre-service science teachers within the context of ESD. Contrary to Ben-Zvi Assaraf and Orion (2005a), Karaarslan constructed system thinking skills in a holistically, not hierarchically. These skills were set as (Karaarslan, 2016, pp.82-85);

STS-1: The System Thinker identifies the meaning and key aspects of Sustainability

STS-2: The System Thinker is able to see nature as a system

STS-3: The System Thinker is able to identify components of a system

STS-4: The System Thinker is able to analyze the interconnections among the aspects of sustainability by considering causes and consequences of the issues

STS-5: The System Thinker is able to recognize hidden dimensions in a system

STS-6: The System Thinker is able to recognize that he/she is a part of this system and has a responsibility in the system.

STS-7: The System Thinker is able to consider the relationships between past, present and future.

STS-8: The System Thinker is able to recognize cycling nature of the system.

STS-9: The System Thinker develops empathy with other people

STS-10: The System Thinker is able to develop empathy with non-human beings.

STS-11: The System Thinker is able to build sense of place

STS-12: The System Thinker is able to adapt systems thinking perspective to his/her daily life.

Even though the concept of systems thinking is being defined as competency (UNECE, 2011) or components of sustainability literacy (Nolet, 2009), environmental literacy (Parkin et al., 2004) and scientific literacy (Mun et al., 2015), the researcher of this study believed that systems thinking has much more elements that transcend being a competency or being a component of a context-based literacy as a skill. Systems thinking requires content knowledge (Ben-Zvi Assaraf & Orion, 2005), contextual knowledge (Capra, 1996), procedural knowledge (Nolet, 2009; Capra, 2005), affective domain (Karaarslan, 2016), some skills such as problem-solving (Mun et al., 2015), the development of models (Mun et al., 2015), making forecast in time (Ben-Zvi Assaraf & Orion, 2005; Karaarslan, 2016). In addition, all of the descriptions of sustainability literacy given in this section (e.g., Nolet, 2009; Warren, Archambault & Foley, 2014) can be reinterpreted within the context of systems and systems thinking since they were regarded as one of the key elements while defining them.

## **2.6 Becoming a Solo Artist: Systems Literacy**

From the beginning of defining literacy, many of the researchers have been conducting studies to describe and understand the nature of the literacy contexts (e.g., McBeth, 2006; Stibbe, 2011). Although they have been providing invaluable contributions to the educational literature, we need to have a different standpoint to cope with the challenges of 21<sup>st</sup> century. In this section, previous studies on systems literacy were

summarized and the need for an alternative definition for systems literacy was discussed.

Even though much of the existing literature on systems thinking in educational context preferred to use ‘systems thinking’, *systems literacy* have started to be studied in different disciplines at the beginning of 2000s even though its first pronunciation dated back to 1990s. The definitions of systems literacy as well as its scope are both converged and diverged at some points. These descriptions as well as their context was reported in this part.

A statement of a senior government advisor in the UK government’s Cabinet Office during 90s could be the first idea to cultivate the notion of systems literacy as “Clear systems thinking is one of the basic literacies of the modern world” (as cited in Reynolds, 2011, p.40). Reynolds added that “In the same way effective systems thinking is a literacy that is continually being informed, moulded and (re)shaped by ongoing practice.” (p.40). In the same year, Wood (2012) described systems literacy as “Systems literacy is an evolved form of interdisciplinary research practice and pedagogy that calls for intellectual competence (not necessarily command) in a variety of fields in order to better address specific, real-world environmental problems. In essence, systems literacy combines the study of social history and cultural discourses with a technical understanding of ecosystem processes.” (pp.4-5). Henning and Chen (2012) critiqued that system thinking researchers is focusing on knowledge on the systems and argued that “The start of systems literacy is fact but knowing about systems requires more” (p.471). They defended the idea that being a systems literature demands more than the level of knowledge.

Sweeney (2012) is one of the pioneers to cultivate the notion of systems literacy in educational context. She described systems literacy as ‘level of knowledge about complex interrelationship’ (p.4). In terms of characteristics of systems literacy, she outlined that systems literate individuals are able to see multiple causes in occurrence of an event as well as grasp the importance of sharing commons such as water, air, land. Contrary to some experts, as she reported, she claimed that many children have

innate ability to see systems behavior without having formal training to learn how to do it. Moreover, Sweeney added that cultivating and developing systems literacy is relatively simple since contexts in daily life lend itself to achieve this.

Dubberly (2015) presented a systems literacy manifesto in Third Symposium of Relating Systems Thinking to Design. He argued that humanity is experiencing difficult times by dealing with wicked problems and promoting innovations in economy and society which brings a comprehension of systems. He described that basic systems literacy for inventors, developers, and administrators requires three kinds of knowledge as following:

1) a systems vocabulary, ‘the content of systems literacy, that is, command of a set of distinctions and entailments or relationships related to systems); 2) systems reading skills, (skills of analysis, for recognizing common patterns in specific situations, e.g., identifying—finding and naming—a feedback loop); and 3) systems writing skills, (skills of synthesis, for understanding and describing existing systems and for imagining and describing new systems). (p.3)

In addition to these three kinds of knowledge, he provided a comprehensive vocabulary list. He also recommended that offering three complementary courses related to systems thinking could be an optimal number within the context of higher education. On the other hand, Ison and Shelley (2016) claimed that systems literacy encompasses systems thinking and systemic sensibility could be the overarching term for these two. They also highlighted that cultivating systems literacy and systems thinking are not on educational agenda which might be a limitation to achieve systems-literate individuals.

To recap, systems literacy was defined as a relatively new context compared with the other context-based literacies. Among the definitions of systems literacy, only Wood (2012) included the context of social history and cultural discourse and Dubberly (2015) emphasized some skills required to be systems literate. The other available definitions in the literature emphasized cognitive processes of individuals. However, as stated previously, systems literacy requires more than types of knowledge (Henning & Chen, 2012). Accordingly, in the light of the debates on context-based literacy definitions; revision of previous studies; and the effects of milestones 21<sup>st</sup> century

global issues on ecology, economy, and society, the researcher of this study claimed that an alternative framework for systems literacy is needed to proceed in the development of theories related to systems literacy. In addition to these body of knowledge and arguments summarized in this section; the researcher of this study added two significant aspects to be able to provide an alternative framework for systems literacy. The first one is to examine and integrate the principles of systems science (Mobus & Kalton, 2015) to the alternative framework for systems literacy. The former studies included some of the aspects of principles of systems science, but they did not include them in a coherent framework. The second one is related to including a literacy description compatible with the general literary studies. In general, context-based literacy definitions do not have consensus on their definition and components. However, as Stables and Bishop (2001) strongly contended, the definitions of literacy contexts are operational and most of them were not taken into account of the significant arguments in general literary studies. Thus, they failed to include the philosophy or theoretical framework which might lead to some difficulties to proceed in the area.

For these reasons, the researcher embraced these critiques and intended to provide an alternative framework for systems literacy by integrating principles of systems science and a general literary framework. Providing an alternative framework for systems literacy within the context of systems science, systems thinking, and literacy studies may offer another stance to existing literacy studies and lead to reconsider the place of systems and systems thinking in educational context. In the subsequent sections, principles of systems science and framework of literacy elements were introduced.

### 2.6.1 General Principles of Systems Science

As systems literacy should cover the principles of systems science, an approach was selected to represent general principles of systems science. Mobus and Kalton (2015) specified 12 principles that can be applied to *complex adaptive systems* (CAS) and many other systems in their book “Principles of Systems Science”. These principles were used in this study to frame the scope of systems literacy from systems science perspective. The principles are as following (pp.18-19, **bold parts** are added):



**PR1.** *Systemness*: Bounded networks of relations among parts constitute a holistic unit. Systems *interact* with other systems, forming yet larger systems. The universe is composed of systems of systems.

**PR2.** Systems are *processes* organized in *structural and functional hierarchies*.

**PR3.** Systems are themselves, and can be represented abstractly as, *networks of relations* between components.

**PR4.** Systems are *dynamic* on multiple time scales.

**PR5.** Systems exhibit various kinds and levels of *complexity*.

**PR6.** Systems *evolve*.

**PR7.** Systems encode *knowledge* and receive and send *information*.

**PR8.** Systems have *regulation* subsystems to achieve stability.

**PR9.** Systems contain *models* of other systems (e.g., protocols for interaction up to anticipatory models).

**PR10.** Sufficiently *complex, adaptive* systems can contain *models of themselves* (e.g., brains and mental models).

**PR11.** Systems can be *understood* (a corollary of #9)—science.

**PR12.** Systems can be *improved* (a corollary of #6)—engineering.

#### **2.6.1.1 Matching the General Principles of Systems Science with Systems Thinking Skills**

As stated in the former sections, systems thinking has been evolving with systems science simultaneously. Therefore, studies including systems thinking are also included the principles of the systems as well. We can see in the literature that these 12 principles are overlapped by some of the systems thinking skills (STS) proposed by systems thinking researchers (e.g., Ben-Zvi Assaraf & Orion, 2005a; Feriver, Olgan & Teksöz, 2019) within educational context. These 12 principles and overlapping STS were summarized in Table 2.4. This table was constructed by the researchers to indicate principles of systems science and overlapping systems thinking skills.

**Table 2.5**

*The Principles of Systems Science and Overlapping System Thinking Skills*

| The Principles of Systems Science                                                                                                                                                                                                                              | Overlapping Systems Thinking Skills in Educational Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>PR1.</b> “Systemness: Bounded networks of relations among parts constitute a holistic unit. Systems <i>interact</i> with other systems, forming yet larger systems. The universe is composed of systems of systems” (Mobus &amp; Kalton, 2015, p.18)</p> | <p>“The ability to make generalizations” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Seeing nature as a system” (<i>Karaarslan, 2016, p.10</i>)</p> <p>Systems thinking and interdependence (<i>Nolet, 2009</i>)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <p><b>PR2.</b> “Systems are processes organized in structural and functional hierarchies” (Mobus &amp; Kalton, 2015, p.18)</p>                                                                                                                                 | <p>“The ability to identify the components of a system and processes within the system” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Understanding the hidden dimensions of the system” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Identifying components of a system” (<i>Karaarslan, 2016, p.10</i>)</p> <p>Ability to see interactions and patterns among the objects and processes (<i>Sterling et al.,2005</i>)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <p><b>PR3.</b> “Systems are themselves, and can be represented abstractly as, networks of relations between components” (Mobus &amp; Kalton, 2015, p.18)</p>                                                                                                   | <p>“The ability to identify relationships among the system’s components” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“The ability to organize the systems’ components and processes within a framework of relationships” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“The ability to understand the cyclic nature of the systems” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>Understanding the hidden dimensions of the system (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Recognizing cyclic nature” (<i>Karaarslan, 2016, p.10</i>)</p> <p>Seeing environmental, economic, and social constructs as interrelated systems possessing recurring patterns. (<i>Nolet, 2009</i>)</p> <p>Ability to see out of the box, network thinking (<i>Sterling et al.,2005</i>)</p> <p>Ability to see interactions and patterns among the objects and processes (<i>Sterling et al.,2005</i>)</p> |
| <p><b>PR4.</b> “Systems are dynamic on multiple time scales” (Mobus &amp; Kalton, 2015, p.18)</p>                                                                                                                                                              | <p>“The ability to identify dynamic relationships within the system” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Thinking temporally: retrospection and prediction” (<i>Ben-Zvi Assaraf &amp; Orion, 2005a, p.523</i>)</p> <p>“Dynamic thinking” (<i>Feriver, Olgan &amp; Teksöz, 2019, p.20</i>)</p> <p>“Time Dimension” (<i>Feriver, Olgan &amp; Teksöz, 2019, p.21</i>)</p> <p>“Considering relationship between past present and future” (<i>Karaarslan, 2016, p.10</i>)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

Table 2.5 cont. 'd

| The Principles of Systems Science                                                                                                                                             | Overlapping Systems Thinking Skills in Educational Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>PR5.</b> “Systems exhibit various kinds and levels of <i>complexity</i>” (Mobus &amp; Kalton, 2015, p.18)</p>                                                           | <p>“One-way Causality” (Feriver, Olgan &amp; Teksöz, 2019, p.9)</p> <p>“Big Picture Thinking” (Feriver, Olgan &amp; Teksöz, 2019, p.3)</p> <p>“Understanding System Mechanisms” (Feriver, Olgan &amp; Teksöz, 2019)</p> <p>“Hidden Dimension: Looking Beyond the Surface” (Feriver, Olgan &amp; Teksöz, 2019, p.7)</p> <p>“Recognizing hidden dimensions” (Karaarslan, 2016, p.10)</p> <p>Seeing environmental, economic, and social constructs as interrelated systems possessing recurring patterns (Nolet, 2009)</p> <p>Ability to see out of the box, network thinking (Sterling et al., 2005)</p> |
| <p><b>PR6.</b> “Systems <i>evolve</i>” (Mobus &amp; Kalton, 2015)</p>                                                                                                         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <p><b>PR7.</b> “Systems encode <i>knowledge</i> and receive and send <i>information</i>” (Mobus &amp; Kalton, 2015)</p>                                                       | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <p><b>PR8.</b> “Systems have <i>regulation</i> subsystems to achieve stability” (Mobus &amp; Kalton, 2015)</p>                                                                | <p>“Feedback Thinking” (Feriver, Olgan &amp; Teksöz, 2019, p.9)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <p><b>PR9.</b> “Systems contain <i>models</i> of other systems (e.g., protocols for interaction up to anticipatory models)” (Mobus &amp; Kalton, 2015)</p>                    | <p>“Developing sense of place” (Karaarslan, 2016, p.10)</p> <p>“Adapting systems thinking perspective to personal life” (Karaarslan, 2016, p.10)</p> <p>Seeing environmental, economic, and social constructs as interrelated systems possessing recurring patterns. (Nolet, 2009)</p>                                                                                                                                                                                                                                                                                                                 |
| <p><b>PR10.</b> “Sufficiently <i>complex, adaptive</i> systems can contain <i>models of themselves</i>” (e.g., brains and mental models) (Mobus &amp; Kalton, 2015, p.20)</p> | <p>“Recognizing own responsibility” (Karaarslan, 2016, p.10)</p> <p>“Adapting systems thinking perspective to personal life” (Karaarslan, 2016, p.10)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <p><b>PR11.</b> “Systems can be <i>understood</i> (Mobus &amp; Kalton, 2015, p.20)</p>                                                                                        | <p>“The ability to make generalizations” (Ben-Zvi Assaraf &amp; Orion, 2005a, p.523)</p> <p>“Thinking temporally: retrospection and prediction” (Ben-Zvi Assaraf &amp; Orion, 2005a, p.523)</p> <p>“Problem Solving” (Feriver, Olgan &amp; Teksöz, 2019, p.22)</p> <p>“Analyzing interconnections” (Karaarslan, 2016, p.10)</p> <p>“Developing empathy with people” (Karaarslan, 2016, p.10)</p> <p>“Developing empathy with non-human beings” (Karaarslan, 2016)</p> <p>“Adapting systems thinking perspective to personal life” (Karaarslan, 2016, p.10)</p>                                         |
| <p><b>PR12.</b> “Systems can be <i>improved</i>” (Mobus &amp; Kalton, 2015, p.20)</p>                                                                                         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

Different from other system scientists (e.g., Mobus & Kalton, 2015), system thinking researchers intend to explore (1) how individuals in different ages perceive systems; (2) how can we use these perceptions to “*effectively participate in and engage with them [systems]*” (Henning & Chen, 2012, p.470, brackets added); and (3) how can we integrate systems thinking in educational contexts. For simplicity, researcher of this study assumed that the aspects of systems thinking are also embedded within the general principles of systems science and correspondingly, common characteristics of systems thinking contributed to shape the notion of systems literacy.

## **2.6.2 Tailoring the Principles of Systems Science to A Literacy Context**

Stables and Bishop (2001) strongly argued that the definitions of literacy contexts are operational and most of them were not constructed by considering the important arguments in general literary studies. Hence, they may lack of philosophy or theoretical framework of literacy which may result in having difficulties to proceed in this area. Moreover, they elaborated the notion of literacy in a way that everything in the environment or in our surrounding can be seen as ‘text’ to be read. For these reasons, the researcher of this study considered these critiques and describe systems literacy by using a general literary framework. Compatible with the general literary frameworks, the definitions done by Williams and Snipper (1990) and Stables (1998) were guided to portray systems literacy. Whereas the definition of William and Snipper covered general definition of literacy, Stables accommodated William and Snipper’s definition within the context of environmental literacy. By using these theoretical frameworks, *systems literate individuals* can be described as *functional systems literacy*, *cultural systems literacy*, and *critical systems literacy*. Moreover, general principles of systems as well as common characteristics of systems thinking studies were also included while constructing the framework of systems literacy.

### **2.6.2.1 Functional Literacy**

In general, functional literacy corresponds to literal comprehension (William & Sniper, 1990) on a superficial level in a given context. As Stables (1998) exemplified “It allows you to read a story, but does not account for whether you can draw any

implications from it.” (p.157). However, Stables elaborated this literal comprehension while defining functional environmental literacy as it requires a series of multifaceted skills and construction of knowledge as well. He exemplified as functionally environmental literate individuals could be able to recognize a tree by using observational skills as well as their background knowledge.

Stables (1998) highlighted that even though functional literacy was not sufficient itself, it is also one of the indispensable fragments for the critical and cultural literacy. The reason for insufficiency is that it may not engage the individuals in an action even though they may be motivated to participate in it. Hence, *cultural literacy* and *critical literacy* are needed.

#### **2.6.2.2 Cultural Literacy**

Stables (1998) and Williams and Snipper (1990) denoted that cultural literacy demands an ability to comprehend the importance of cultural icons on society. These icons can be either living or non-living things or both at the same time. In this element of literacy, cultural literacy permits individuals to appreciate the importance of these icons in human culture and the reasons for their importance. However, Stables (1998) forewarned that cultural literacy does not mean a cultural analysis, but rather it refers to general insight of a culture. Some sort of cultural analysis requires critical literacy in addition to cultural literacy.

Insofar, Stables (1998) highlighted that adequate level of literacy in both functional and cultural state enables individuals to cultivate critical literacy on their own. He added that having merely functional environmental and cultural environmental literacy makes no sense unless critical literacy is present. In the next part, critical literacy and its rationale were given

#### **2.6.2.3 Critical Literacy**

Critical literacy involves “the ability to 'get behind' the text to interpret it in terms of its ideological underpinnings...” (Stables, 1998, p.157). As stated in the former

section, Stables (1998) argued that critical literacy demands both functional and cultural literacy. He elaborated his argument as (p.160)

Critical environmental literacy relies on functional environmental literacy because both environmental debate and environmental action rely on information. Critical environmental literacy relies on cultural literacy not simply because environmental debate and action need to be grounded in an awareness of the norms and values of, say, national cultures, but because influence on environmental change demands an understanding of the norms and values of the dominant culture.

Based on this description, critical literacy could be summarized as (1) including necessary skills to grasp a context in terms of cultural, social and political aspects and (2) developing a personal and social response to that context. Moreover, Stables exemplified that individuals who have critical environmental literacy are able to explore the factors influencing an environmental change and suggest possible actions that may revert that environmental change. It triggers individuals to think about following questions (Stables, 1998, p.160)

'What does [a place or an issue] mean to me?'; 'What does it mean to us, or to others?'; 'What are the consequences of carrying on in this way [in relation to this place or this issue]?'; 'Should we act differently, and if so how?'; 'How do we translate our values into effective action, and are our values themselves ready for change as a result of what we now know or feel?'.

When the characteristics of critical literacy /critical environmental literacy examined, it could be deduced that some constructs are further needed to be defined operationally in order to clarify the description of critical literacy. For example, to explore possible factors; translate values into effective actions; and suggest possible actions to revert or mitigate to a change, some additional constructs are essential to be included within alternative framework of systems literacy. At this point, the arguments of Henning and Chen (2012) could be invaluable to be considered. They mentioned some of the constructs that are compatible with systems thinking within the context of systems principles. Accordingly, these constructs could have a potential to integrate the notion of critical literacy.

#### **2.6.2.3.1 Human Beings as An Integral Element of Systems**

Henning and Chen (2012) outlined that human beings are one of the visible elements of systems. Further, they also argued that human beings are also a system itself having both visible and invisible elements and these elements have interactions with other systems. According to their summary (pp.473-474),

The beliefs (O'Connor, 1997), information (Gharajedaghi, 2005), values (Checkland, 1999; Gharajedaghi, 2005), and ideas that individuals possess are intangible elements of a system; so too are the goals each person possesses. Some goals are officially endorsed by a system (Dettmer, 2007; Haines, 1999); some are not (Checkland, 1999). Some goals are known to those who possess them; some are not (Brynteson, 2006). Some goals coexist harmoniously; some conflict (Checkland, 1999). Some of these intangibles—beliefs, information, values, ideas and goals—remain relatively unchanged over time; some change rapidly. And all are informed by the beliefs, information, values, ideas and goals of other people within the system.

In a similar manner, researcher of this study believes that defining critical literacy within the context of systems literacy context demands more than a cognitive process and requires more than level of knowledge/information about systems. Since human beings are also subsystems of all the systems both as an individual and as a group of people, their beliefs, information, values, ideas, and goals should be also taken into account while constructing and assessing critical literacy. Consequently, these invisible elements are also interacted with both human systems as well as other systems. Accordingly, based on the definition of Stables (1998) and Henning and Chen (2012), the constructs of beliefs, action strategies, self-efficacy beliefs, motive concerns, emotional response, and motivational orientation were determined by the researcher within the context of critical systems literacy. As there are different approaches for these constructs in the literature, the researcher of this study chose operational definitions to interpret the elements of human system.

For the construct of belief, Fishbein and Ajzen's theoretical framework (1977) were used to classify beliefs as descriptive, inferential, and informational belief. Descriptive beliefs are shaped by direct experiences of individuals, whereas inferential belief derived from descriptive beliefs. On the other hand, informational belief is formed

from an outside source such as TV, papers, journals, books, magazines, lecturers, friends or coworkers.

As a theoretical framework for motive concerns, Stern and Dietz' theory of the value basis of environmental concern (1994) was used. They defined social altruistic concerns as values that influence people to evaluate environmental issues by means of costs or benefits for a civic, a nation or all humanity. On the other hand, egoistic concern interprets environmental issues on their own needs. Biospheric concern refers to appraising environmental issues based on its probable costs or benefits to ecosystems (Stern, Dietz, Kalof & Guagnano, 1995). They outlined that this tripartite classification may have a role in the intentions to act for the protection of the environment. In terms of self-efficacy beliefs, Bandura's theoretical framework was selected (1977). He defined self-efficacy beliefs as following: "the beliefs in one's capabilities to organize and execute the courses of action required producing given attainments" (Bandura, 1977, p.3). These beliefs influence the choice of actions, performances, the level of perseverance for obstacles, the durability, and the level of success (Bandura, 1977). This framework emphasized that high self-efficacious individuals have a tendency to engage in challenging goals, persist difficulties and have relatively higher level of motivation (Locke & Latham, 1990). In contrast, low self-efficacious people might avoid performing an action (Pintrich & Schunk, 2002). In terms of systems literacy in water context, high self-efficacy beliefs could be considered as an indicator for monitoring water consumption behavior.

Ryan and Deci (2000) provided a framework for motivational orientations of individuals. Their fundamental distinction of intrinsic and extrinsic motivation was selected as a framework for the motivational orientation. Their basic definitions were as following (Ryan & Deci, 2000, p.55): "The most basic distinction is between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome". Individuals' motivational orientations were classified based on these two types of motivational orientation.



To sum up, the need for systems literacy and the requirements to provide alternative framework for systems literacy were introduced. Within the context of principles of systems science, human system and its possible constructs were also operationally defined. On the other hand, the alternative framework systems literacy and systems literacy in water system context will be provided under the chapter of findings. In the next chapter, to provide an insight to systems literacy in water system context, water studies conducted in K-12 education were summarized.



## CHAPTER 3

### REVIEW OF LITERATURE ON WATER STUDIES ON K-12 STUDENTS

*“Water is the driving force of all nature.”*

*Leonardo Da Vinci (1452–1519)*

#### **3.1 Studies on Water in the Field of K-12 Education**

The purpose of writing this chapter is to recap briefly the studies on water in educational context. This chapter followed the chronological order to portray how the literature evolved in time.

##### **3.2.1 Earlier Water Studies in the Field of K-12 Education**

This part covered the studies conducted until the end of the 20<sup>th</sup> century in the accessible literature. Earlier educational studies within the context of water tended to include children in different ages together to see how their understanding evolved as they grow older (e.g., Piaget, 1929, Bar, 1989). The orientation of the literature was mainly alternative conceptions and misconceptions. For example, affective domain was not appeared in the studies until 1980s (e.g., Osborne & Cosgrove, 1983).

The oldest study reported in the literature related to children’s understanding of water was the works of Piaget (Piaget, 1929). He studied with the children to explore their notions on the clouds and rain. Accordingly, Piaget reported three stages among

children in different age groups. At first stage (*average age was 5-6*), children imagined that either the clouds are man-made, or God created them. Clouds and rainwater are separate entities and children indicated no connection between them. At the second stage (*average age was 6-9*), they started including natural phenomena built on 'morphological analogies'. Children at this stage stated that clouds are composed of smoke but still, they lack water. However, clouds have potential to be precursor of rain. In the third stage (*average age was 9-10*), children identified that clouds are composed of water even though there were alternative conceptions –i.e., clouds are composed of air, heat etc.- In terms of the source of rainwater, they had ability to relate clouds and rain together at the third stage. In another study conducted in 1976, Za'rour worked with children between 6-9 ages. The aim of the study to examine Lebanese students' understandings related to the source of rainwater (Za'rour, 1976). Among the all participants, approximately the half of the children reported that the source of rainwater is the clouds but 44% of them failed to indicate that rainwater came from seawater. On the other hand, 25% of the third and fourth graders linked rainwater to evaporation and the water cycle, whereas younger students indicated the source of rainwater as religious.

Literature on the conceptions of water among children were concentrated on alternative conceptions and misconceptions beginning from the 80s. Mills (1983) aimed to construct a water knowledge instrument (WRKA) (1) to investigate the level of knowledge of recent high school graduates, (2) the validity and reliability evidences of the instrument; (3) to identify factual knowledge on water; and (b) detect significant differences within subgroups of the population in terms of gender, residence, and science/non-science major. In terms of validity evidences, panel of experts gave feedbacks to finalize the instrument. On the other hand, reliability coefficient was calculated as 0.77 for the 46 items that administered to 159 participants. The findings showed that participants' scores were lowest in social concepts (contemporary issues 25.7%, water resource management 28.4%, and historical influences 36.4%) as compared to natural science topics (hydrological cycle 80.3%, chemical and physical

properties 52.3%). Mills articulated that higher scores can be attributed to the curriculum, whereas lower scores in the categories were not included the content of the high school curriculum. Besides, female students were group in the upper and lower quartiles, whereas male students located in the 2<sup>nd</sup> and 3<sup>rd</sup> quartiles. In terms of residence, students living an urban area had relatively higher scores than rural students. Surprisingly, non-science majors' scores tended to be better than science major students, but Mills denoted that no specific information was available to illuminate this difference. Based on the results, he recommended to replicate this study with other populations, with larger sample sizes. Moreover, it was also recommended that experimental study and curriculum analysis could be added to further studies.

Another study was investigated the effect of an intervention related to water conservation on students' knowledge and attitudes towards efficient water use (Birch & Schwaab, 1983). This study could be one of the earliest studies that included a construct related to affective domain in the accessible literature. A Solomon 4-Group Design was chosen, and the sample was 843 students in 7<sup>th</sup> grade. Students' knowledge was determined by using a multiple-choice test composed of items related to water conservation. Their attitudes were determined by using a Likert scale. They reported that pre-test scores of the four groups indicated similar knowledge and attitude about water use before intervention. The results revealed that post-test knowledge scores of the treatment groups were higher than the control groups ( $p < .0001$ ). In a similar manner, attitude scores of the treatment groups were significantly higher than the control groups ( $p < .0001$ ). A one-sample *t*-test was conducted to evaluate whether the difference between pretest and posttest scores are statistically significant. The results revealed that Group 1 (experimental group) had statistically significant scores knowledge and attitude scores in treatment Group 1 ( $p < .0001$ ). Moreover, there was statistically significant correlation between attitude and knowledge post-test scores ( $r=.46, p<.0001$ ) of treatment groups. Based on the results, the researchers concluded that knowledge and attitudes related to the water conservation might be enhanced via an intervention. For the future studies, they recommended that follow-up tests could

be added to examine retention of the intervention since their intervention was implemented in a relatively short time interval. Moreover, they also suggested to examine students' water consumption behavior in a real context where their actual water consumption behavior could be observed such as a summer camp.

Osborne and Cosgrove (1983) conducted a study in New Zealand to examine children's conceptions on the changes of state of water. A total of 43 participants between 8-17 ages were interviewed by using clinical interview technique. The findings were classified based on their views on boiling, evaporation, condensation on a cold surface and from steam, and melting. Based on children's views, they concluded that (1) children do not learn the meanings of scientific terms in depth but they are able to match the correct terms with a phenomenon; (2) although older children are exposed to science teaching, they have still alternative conceptions akin to younger students' conceptions derived from observations; (3) Some alternative conceptions were still resistant in older students –i.e. water breaks down into hydrogen and oxygen during boiling.-; and (4) science teaching offers abstract concepts to the students and therefore, they hardly relate them into their daily life experiences. Additionally, researchers also denoted that students come to the class by having conceptions related to daily life observations which are often resistant to change. Thus, some of these conceptions can persist or changed in unexpected ways after exposed to instruction as in the boiling event –breaking down into hydrogen and oxygen.

Varda Bar was one of the researchers that conducted multiple studies related to the students' conceptions on water and water cycle as a function of age. The aim of the first study was to explore Israeli children's views on water cycle (Bar, 1989). Bar hypothesized that the notions related to the water cycle can be classified into stages and these stages could be related to the level of understanding pertinent to phase changes. Accordingly, 300 students were participated in the study. The range of the grade level of the students were from kindergarten to 9<sup>th</sup> grade level. The number of male and female students were equal, and students were coming from families with middle or upper middle socio-economic status. Clinical interview was used to examine

children's views on evaporation, clouds, and rainfall. Based on the interview analysis, Bar proposed three stages for the development of children's ideas from a concrete stage to abstract stage. These three stages and views of the children were summarized in table given below.

**Table 3-1**

*Summary of Three Stages and Views of Children*

|     | Level of Conservation                                                               | Physical Concepts                                    |                                    | Natural Phenomena                                                                |                                                      |                                                                                                            |
|-----|-------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
|     |                                                                                     | Evaporation*                                         | Boiling**                          | Rainfall                                                                         | Nature of Clouds                                     | Source of Clouds                                                                                           |
| III | Amount of liquid is conserved.<br>Air exists always                                 | Water Change into Vapour                             | When water boils vapour is created | Condensation occurs, drops become bigger and fall                                | Are made of vapour                                   | Water evaporates from many sources and from the sea                                                        |
|     | (Air is conserved)                                                                  | Water changes to vapour. Evaporates into a Container |                                    | whole*** clouds go down as fog                                                   | sponges with drops of water in them                  | Water evaporates from many sources or the sea<br>water evaporates from many sources<br>sun boils sea water |
| II  | Amount of liquid is conserved<br>Air is created by motion<br>(Air is not conserved) | Water penetrates<br>solid objects                    | When water boils vapour is created | Clouds*** are shaken by the wind or sweat<br>clouds get scrambled<br>clouds open | sponges with drops of water in them<br>bags of water | The sun "boils" sea water<br>Refills by sea water                                                          |
|     | Amount of liquid is not conserved<br>Air is not conserved                           | Water disappears                                     | When water boils vapour is created | Clouds open<br>Clouds explode                                                    | Bags of water                                        | Made by God or man are kept above the sky                                                                  |

(Retrieved from Bar, 1989, p. 496)

In addition to the table given above, Bar highlighted that children constructed their own theory in each stage based on their physical knowledge. In the case of not having a necessary knowledge for phase change, they tended to explain a phenomenon in which water appeared in liquid state. Based on the findings, Bar concluded that the concept of evaporation is a prerequisite for grasping the nature of the rain. Moreover,

children' alternative views were compatible with the history of the development of the concepts.

To replicate and extend the study of Osborne and Cosgrove (1983) in another context, Bar and Travis (1991) conducted a research on Israeli students' understandings of phase changes. The aims of their research were to identify levels of development for the children aged 6-14 to reveal their alternative conceptions on phase changes in each level and to outline the reasons for these conceptions. Accordingly, 83 pupils participated in the study and three different data collection techniques as oral test, open-ended written test, and multiple-choice test were used. They summarized the alternative conceptions in three age levels as given in table below.

**Table 3-2**

*Summary of Alternative Conceptions in Three Levels of Development*

|                    |                           | Age                 |                     |                      |
|--------------------|---------------------------|---------------------|---------------------|----------------------|
|                    |                           | 7 years<br>3 months | 9 years<br>3 months | 11 years<br>3 months |
| Evaporation        | Water disappeared         | 23%                 | 12%                 | 20%                  |
|                    | Water penetrated solids   | 65%                 | 47%                 | 18%                  |
|                    | Evaporated into container | 7%                  | 27%                 | 34%                  |
|                    | Evaporated and scattered  | 5%                  | 18%                 | 24%                  |
| In the bubbles     | Water                     | 40%                 | 25%                 |                      |
|                    | Air                       | 25%                 | 40%                 | 75%                  |
|                    | Water vapor               | 15%                 | 15%                 | 15%                  |
|                    | Other                     | 20%                 | 20%                 | 10%                  |
| Existence of vapor | Kettle in the room        |                     |                     |                      |
|                    | Only in winter            |                     |                     |                      |
|                    | Always                    | 15%                 | 35%                 | 55%                  |
|                    | Never                     | 80%                 | 60%                 | 37%                  |

(Retrieved from Bar & Travis, 1991, p. 378)

In the concept of evaporation, they reported the proportion of selecting the correct answer increased as pupils grow older; however, alternative conceptions were not disappeared completely. Boiling, on the other hand, was one of the concepts that was relatively easy to identify even in the younger pupils. They could be able to aware of

that water changes from liquid to gaseous state in the boiling. Nevertheless, they could not provide a similar explanation for the concept of evaporation. Yet, pupils had difficulty to identify the ingredient of water vapor and revealed some misconceptions given in Table 3-2. The condensation was the last concept investigated by the researchers. As they reported, the development of this concept was started with the development of the evaporation in students' minds. This development occurred as they grow older. In brief, the concept of boiling was formed and then the concepts of evaporation and condensation are added in pupils' understanding as a function of age. Based on the alternative conceptions that they had detected, Bar and Travis (1991) informed science teachers that pupils' understanding of the concepts are often shallow. Their alternative conceptions become apparent when students explain the processes occurred in those concepts. What is more, the researchers emphasized that multiple-choice tests might be beneficial to detect misconceptions since students tend to choose misconception among the alternatives. To conclude, two outcomes of Osborne and Cosgrove were verified by Bar and Travis which are (1) some of the alternative conceptions can be nurtured by teaching; and (2) students who recognizing the concept in given context might not be able to describe the physical processes in that concept. As an implication, Bar and Travis recommended that phase changes could better be taught by using everyday experiences to eliminate alternative conception in this context.

In another work, Bar and Galili investigated (1) pupils' understandings of evaporation as a function of age; (2) the interactions among these understanding, conservation of matter, and the nature of the air; (3) influence of the testing method on the responses; and (4) context-dependency of the understandings (Bar & Galili, 1994). Four data collection stages were employed, and an interview was integrated into each stage. During the first and second stages, interviews were performed with 293 and 165 participants, respectively. In the third stage, a total of 260 students were administered to written test. At the last stage, extraordinary responses of 17 participants were checked. Based on the analysis, Bar and Galili found that the conceptions on



evaporation can be summarized as a function of age from five-year old to 14-year old in a hierarchical manner. They also reported that students' views were context dependent. Based on the findings, they proposed that the concept of water cycle should be introduced at age nine or fourth grade level after the concept of evaporation would be understood by the pupils.

Brody (1993) presented a literature review paper related to the pupils' understanding of water and water resources in the Annual Meeting of the American Educational Research Association. Content analysis was used to portray what is known about pupils' understanding in water context. He examined their knowledge within four categories as (1) physical and chemical properties; (2) biology; (3) earth systems; and (4) water resources. Based on the analysis, he reported that physical and chemical properties of water was the most frequently studied content among the others. These studies showed that pupils' level of knowledge is insufficient and there are alternative conceptions on this content. In a similar vein, students had rudimentary understanding in biological concepts too and have misconceptions even though a limited number of studies existed in the literature. Water cycle, as an Earth system was also very a challenging concept to be grasped by the students. Brody denoted that the concept of water resources was the one that students had least amount of information. Besides the summary of the literature pertinent to these four concepts, Brody also reported the similar characteristics of the pupils drawn from different studies. He highlighted that even though pupils were exposed to science teaching, they had similar alternative conceptions with the younger ones. Even some cases, older pupils had more alternative conceptions. Additionally, pupils resisted to change their conceptions after the science instruction, and they tended to explain the phenomena related to water based on their daily life observations, inferences, and popular media. As a recommendation, Brody emphasized that students' understanding pertinent to water and water resources remained intact and needs to be explored including its historical and cultural perspectives.

In 1999, a study was conducted to examine students' drawings of a river basin pertinent to water cycle (Dove, Everett, & Preece, 1999). A total of 306 students aged from 9 to 11 participated in the study from five schools. Their drawings were classified into five stages of understanding. Further, follow-up interviews were completed with 60 children. The content analysis showed that the majority of children indicated rivers flowing from left to right, or down the page. Additionally, student painted surface flow of the water within the context of rural area. The researchers also reported that as students' understandings evolve, they start to include the elements in their drawings related to water basin. Based on the results, they forewarned the teachers that they should be aware of students' alternative conceptions to overcome barriers in learning. For example, the teacher must indicate explicitly that surface flow can in any direction while they taught water cycle.

To sum up, earlier educational studies conducted within the context of water tended to include children in different ages together to see how their understanding evolved as they grow older. What is more, water was one of the concepts that studied specifically in cognitive domain. Affective domain, on the other hand, was not frequently studied in those years. In the next section, studies conducted after 20s were reported.

### **3.1.2 Water Studies in the Field of K-12 Education during 21<sup>st</sup> Century**

Earlier studies summarized in the previous section focused on students' conceptions with respect to developmental stages and alternative conceptions / misconceptions in water context. Moreover, they tended to include different ages in the studies to see the patterns of conceptual development. The studies beginning from 20s started to focus on specific ages or grade levels. Even though the conception studies continue to be conducted in water context, center of attention was shifted from alternative conceptions to Earth systems and systems thinking perspectives. This section was not written as following strictly the chronological order as in the previous section. Instead, multiple studies of the research groups were given in a coherent manner to increase readability.

Henriques (2002) reviewed literature on pupils' conceptions on weather and included some components of water cycle in her study within the context of science education. Henriques reviewed the standards and reported that the concept of weather was mainly given in geography instead of science. In science context, water cycle, properties of water like phase changes and cloud formation, and heat exchange were introduced to the student via visual tools and experiments. She categorized alternative conceptions in the literature as (1) properties of water; (2) phase changes; (3) water cycle; (4) cloud formation and precipitation; (5) the atmosphere; (6) greenhouse effect/global warming; and (6) differentiation of the terms weather and climate. She outlined that most of the alternative conceptions of the pupils were related to the water in physical science rather than the Earth science. She provided a useful list with the six categories given above as an appendix with specific grade level.

Butler and MacGregor (2003) introduced the program of GLOBE which is an educational tool for science education as well as environmental education to enhance pupils' achievement in science, mathematics, geography and use of technology. The aim of this program to build bridges between scientists and students. A total of 11,664 schools from U.S and the other countries ( $n=102$ ) had partnership with this program. At first, teachers were prepared to guide pupils to collect data for environmental parameters scientifically. Then, students engaged with the program. Data gathered by the students were available on the web. Butler and MacGregor (2003) assessed the 6-year of implementation of the program and reported that GLOBE improve the pupils' decision-making capability through scientific data and increase their awareness towards the nature. The content of GLOBE included water cycle and watershed cases.

Examining the concept of groundwater in pupils' mind within the context of science education was studied by Dickerson and his colleagues (Dickerson & Dawkins, 2004; Dickerson, Dickerson, Sickel, & Hay, 2005; Dickerson, Penick, Dawkins, & Sickel, 2007). They mainly criticized lack of emphasis to groundwater concept and concentrating on the macro-scale of water concepts such as water cycle. In the first study (Dickerson & Dawkins, 2004), they focus on eight grade students' conceptions

on groundwater. Referring the national standards, it was expected eight grade students to have necessary information on groundwater and its interaction with the water cycle. A total of 18 students were administered to an instrument having two questions: one multiple-choice test item and one drawing task before and after the treatment. The drawings were examined based on the categories of groundwater formation, movement, and storage. Additionally, in-class discussions were also analyzed. The findings revealed that eight grade students had 'naïve conceptions' but these were hard to detect due to students' way of using scientific terms. Even though they used the terms porosity and permeability, they had difficulty to explain them. They commonly mistakenly used the terms "underground stream/pool". The researchers also reported that spatial reasoning, visual aids in the textbooks, written and media, daily life experiences, and discourse with the other people about groundwater interfered with students' conception. The researchers highlighted that necessary steps should be taken by the educators and scientific community. They recommended that in-service teachers should realize these alternative conceptions and prepare their lectures considering that aspect.

To broaden the study, Dickerson et al. (2005) worked with the three groups (29 of them 12<sup>th</sup> grade; 44 of them undergraduate and graduate students) to examine their conceptions on structure and scale of groundwater as well as its importance to them. The instrument was at this time composed of six multiple-choice items. The findings of the study showed that majority of the participants had alternative conceptions on groundwater concepts. In terms of perceived importance, students emphasized its health and economic importance. In another study (Dickerson, Penick, Dawkins, & Sickel, 2007), they articulated the possible problems for having these alternative conceptions on groundwater. They diagnosed four problems as "(a) The Lack of Emphasis in Standards Documents; (b) The Need for Increased Attention to Students' Spatial Reasoning Abilities; (c) The Inadequate Formal Instruction for Science Teachers Concerning Groundwater; and (d) The Difficulty in Designing Appropriate Assessments" (Dickerson, Penick, Dawkins, & Sickel, 2007, pp. 46-47).

In the context of the groundwater, Duffy (2012) structured a dissertation under the supervision of Dickerson aiming to examine sixth grade students' mental models by using 5E approach and using physical models. Mixed-method research design was employed and both qualitative and quantitative data were collected. The findings showed that using physical models enhance students' understanding on porosity and permeability. On the other hand, the author cautioned that pure discovery learning in 5E approach may stimulate alternative conceptions on groundwater. To conclude, it was suggested that teaching groundwater concepts could be more efficient if physical models are used in inquiry-based instructions accompanied with instructor's guide and feedback throughout the model activities.

Ben-Zvi Assaraf and Orion were another research group having multiple studies (Ben-Zvi-Assaraf & Orion, 2005a; 2005b; 2010b; 2010a) in the context of water cycle. Different from the previous studies, their framework was based on systems thinking skills (STS). In one of their research (Ben-Zvi-Assaraf & Orion, 2005a), they examined the development of STS among 8<sup>th</sup> graders. The aims of the research were (1) to examine whether the pupils manage understanding the complex systems; (2) to determine the factors that might affect pupils' cognitive ability related to STS; and (3) to explore the interactions among the components of STS. As a result of literature review and their findings, they listed eight STS as following (Ben-Zvi-Assaraf & Orion, 2005a):

1. The ability to identify the components of a system and processes within the system
2. The ability to identify relationships among the system's components
3. The ability to organize the systems' components and processes within a framework of relationships
4. The ability to make generalizations
5. The ability to identify dynamic relationships within the system
6. Understanding the hidden dimensions of the system
7. The ability to understand the cyclic nature of systems
8. Thinking temporally: retrospection and prediction (p.523).

Ben-Zvi Assaraf and Orion (2005a) prepared a program called 'Blue Planet' and they collected data in three time points as before (pre-test), during, and after (post-test) the program. A total of 70 participants (20 of them in pilot study, 50 of them in main study) from two 8<sup>th</sup> grade classes were participated in the study. The research conducted in three stages. At the first stage, the program 'Blue Planet' was prepared as 45-hour program composed of laboratory approach, outdoor education, and field trip activities to promote pupils' STS. At the second stage, the program was put into practice and the learning environments was examined. During the last stage, synthesizing of the findings were employed. There were 10 different data collection tools employed during the research. Multiple validity and reliability evidences were collected for the data collection tools. Quantitative tools were administered to a relatively large sample, whereas qualitative ones were employed smaller samples (e.g. 30 participants for concept map, 8 participants for interview). During the implementation of the program, one of the researchers participated as an observer. According to the findings, development of STS seemed to follow a hierarchical pattern and, in each level, developing cognitive abilities played an important role to pass the next level. They summarized the findings according to the eight levels of STS. To be reader friendly while summarizing the findings of the study of Ben-Zvi Assaraf and Orion (2005a), I abbreviated them as STS-1, STS-2...STS-8 etc.

To examine STS-1, the researchers analyzed pupils' drawings, pre-test and post-test responses. Pre-drawings revealed that majority of the pupils had lack of understanding about how water cycles and held misconceptions. Moreover, their drawings did not include groundwater and centered around atmospheric part of the hydrosphere. On the other hand, the number of components and processes increased in the post-drawing. Yet, biospheric components such as human being and other living organisms were not drawn in their post-drawing activity. The responses in pre-test revealed some similarities with the pre-drawings. Majority of the participants indicated atmospheric part of the water cycle such as rain, clouds, and evaporation. In the post-test, however, the interactions between hydrosphere and human beings were included as either

component or process. STS-2 was traced from groundwater and human effect perspectives in pre- and post-test responses as well as in drawings. During the program, students attended to the various field trips and reflected their experiences in their post-drawings as a relationship between human beings and the hydrosphere. Additionally, STS-2 was also elaborated within the concept of groundwater. Almost every student indicated new relationships among the components in post-drawings.

STS-3 which was about unifying the components within a context of relationship was traced in pupils' concept maps and drawing. The concept maps showed that approximately 66% of the pupils were able to construct expressive concept maps after the program. The other pupils were able to pair two concepts; yet they failed to construct a map showing these pairs in a meaningful framework. On the other hand, the analysis of drawings of the students revealed that pupils had detached understanding for the system. For instance, even though more than eighty percent of the pupils were aware of the concept of environmental contamination, only one fourth of the pupils were able to integrate this concept to the water cycle. STS-4, ability to generalizing, was explored through the pre-tests, post-tests, and concept maps. Pre-test results revealed that majority of the pupils had limited perceptions on the 'systemic nature' of the water cycle and they were able to explain water cycle in terms of its components. However, in the post-tests, their ability to generalizing about the water cycle was improved.

STS-5 examined the dynamic nature of the water cycle within the context of the groundwater movements as well as phase changes of the water. According to the pre-test results, 66% of the pupils had mental model on groundwater as static lake. However, 50% of them did not change their mental models after the program. In terms of phase changes, *t* test analysis showed an increase ( $t = 2.14, p = .04$ ) between pre- and post-concept maps in terms of dynamic nature of the water. STS-7, which is related to the cyclic nature of the water cycle, was examined through the pre-test, post-test and drawings. Pre-test results revealed that 62% of the participants held the misconception that water cycle has a beginning/ending point. This percentage

decreased to approximately 50% after the program. Moreover, majority of the students' drawing lacked hidden parts of the cyclic nature at the beginning of the program. However, their understanding of the cyclic nature enhanced after the program. Pupils were aware of that the conservation of matter principle was applicable to the cyclic nature of the water. For the dynamic and cyclic nature of the system, Ben-Zvi Assaraf and Orion found that there is statistically significant correlation between them ( $r = 0.63$ ,  $p = .0002$ ). Based on this value, they claimed that developing a STS for dynamic nature is one of the prerequisites for the understanding of the cyclic nature of the water cycle.

The other two STSs, which are STS-6 and STS-8, was about hidden aspects of the systems and thinking temporally. STS-6 was covered under the concept of groundwater. The researchers identified three levels (Level A, B, and C) based on the interview analysis. Only pupils in Level C were nominated as having ability to see hidden dimensions within a system. Based on the researchers' post-interview analysis, five pupils out of the 25 interviewees were able to shift from Level B to Level C. For the STS-8, the researchers denoted that only the students who enhanced their STS-6 were able to improve themselves in thinking temporally. Nonetheless, STS-8 one of the most difficult STS among the others to achieve.

Based on the analysis and the post-test findings, Ben-Zvi Assaraf and Orion (2005a) articulated that despite of the limited STS of the pupils at the beginning, majority of them had great progress on enhancing their STS at the end of the implementation of the program. Based on their observations and 25 pupils' written homework, the researchers reported that individual cognitive differences and the amount of participation to the program were two of the variables that were interacted with the pupils' individual progress. For their third research question, they identified four groups of skills in a hierarchical manner. These groups were summarized in table given below.



**Table 3-3**

*Four Groups of Skills Represented in the Sample*

| <b>Groups of skills</b> | <b>Percentages of the participants<br/>in the sample</b> | <b>Achieved STS</b>     |
|-------------------------|----------------------------------------------------------|-------------------------|
| 1 <sup>st</sup> group   | 70%                                                      | STS-1                   |
| 2 <sup>nd</sup> group   | 50%                                                      | STS-2 and STS-5         |
| 3 <sup>rd</sup> group   | 30-40%                                                   | STS-3, STS-4, and STS-7 |
| 4 <sup>th</sup> group   | 10-30%                                                   | STS-6, STS-8            |

*Table was constructed based on the findings of Ben-Zvi-Assaraf & Orion (2005a)*

Ben-Zvi-Assaraf & Orion (2005a) emphasized that the four groups of skills are ordered, and previous group of skills provide a basis for the subsequent group of STS. Nonetheless, they recommended further studies to examine the STS in different settings (e.g., technological and social systems) with additional variables.

Six year later, Ben-Zvi-Assaraf and Orion (2010a) conducted a retention study for their previous work (2005a) summarized above. They selected four participants from the previous study's sample as four different cases by using maximum variation sampling strategy. During that six years, no specific STS was included in their school curricula. The researchers reported that they used the same research tools after making necessary revisions to make them suitable for a retention study. Besides, the researchers also analyzed the high school curricula and conducted additional interviews with participants' teachers in their high school. Categories emerged from the data are divided into cognitive level and affective level. The list of these categories was summarized in the table given below.

**Table 3-4**

*Summary of the Primary Categories in Ben-Zvi Assaraf's Work*

| <b>Cognitive Level</b>                 | <b>Affective Level</b>                          |
|----------------------------------------|-------------------------------------------------|
| Deductive approach to learning         | Tendency towards external motivation            |
| Inductive approach to learning         | Tendency towards internal motivation            |
| Knowledge integration tendencies       | Perception: learning science in school          |
| Tendency toward metacognitive activity | Social interaction with group mates and teacher |
| Question asking tendencies             | Feeling of self-efficacy                        |
| Participation in experiments           | Dissatisfaction                                 |
| Interaction with the group members     | Performance goals                               |
| Process approach                       | Analysis                                        |
|                                        | Synthesis                                       |
|                                        | Implementation                                  |

*Table was constructed based on the findings of Ben-Zvi-Assaraf & Orion (2010, p.1261)*

Based on the analysis that they conducted and the theory of Felder and Silverman (1988), the researchers classified four different types of learner as 'Metacognitive Learner', 'The Gatherer', 'The Generalizer' and 'The Dynamic-Procedural Learner'. They briefly described each type of learner as following:

- The metacognitive learner was able to reach the highest level of STS and the researchers attributed her achievement to her high level of metacognition. She both used the inductive and deductive learning while she was grasping the interactions among the components, holistic nature of the system and its layers.

- The gatherer was hardworking and a dedicated learner utilizing inductive strategies, remembering the details, and trying to collect them as if they were parts of a puzzle. However, this led her to have detached information despite of having large amount of declarative knowledge. In other word, she failed to use these detached pieces of information to form a framework to explain the nature of the system.
- The generalizer was opposed to deductive learning and liked to see the whole as an initial step rather than examining its parts. While he was learning, he was fond of to know how the components work in a system. The researchers debated that this characteristic could enhance their memory to evoke the components of the system.
- The dynamic-procedural learner tended to use deductive learning strategies and his strategies aimed to learn solely the processes in the system. Hence, the researchers recommended that hands-on activities and visual aids could improve this type of learners' systems thinking skills.

Based on the findings, Ben-Zvi Assaraf and Orion reached a conclusion that once a pupil constructs their mental model on a system, his/her gained systems thinking skills tended to be persistent. Accordingly, the researchers recommended that a learning activity should provide a basis for meaningful learning for pupils so that they could be able to scaffold the systems in their minds. While Ben-Zvi Assaraf and Orion (2010a) described these learners, they also highlighted that the metacognitive learner and the generalizer used deductive reasoning which could be a possible useful construct for gaining systems thinking skills.

In another study, Ben-Zvi Assaraf and Orion (2005b) investigated junior high school students' understandings of water cycle. The sample was composed of 1,000 students whose grade level ranged from 7th to 9th grade. The data was collected from 30 classes in six different schools and five data collection tools were employed. The results were similar with the previous study (Ben-Zvi-Assaraf & Orion, 2005a). Pupils were able to grasp different processes within the context of water cycle; however, they had

difficulties to explain dynamic and cyclic nature of the water cycle. Similarly, some preconceptions and misconceptions in evaporation, condensation, and dissolution were also detected. The pupils mainly explained the atmospheric sub-system of the water cycle and failed to indicate groundwater or misinterpret the nature of the groundwater as static-like lakes. The researchers reported that further studies are needed related to cognitive aspect of the systems thinking in a way that which approaches trigger pupils' cognitive abilities. They also recommended that science education should tailor the human effect to the concepts of natural cycles.

To explore to what extent the elementary students engage with STS, Ben-Zvi Assaraf and Orion (2010b) implemented a similar program revised for the 4<sup>th</sup> grade level and assess systems thinking skills of the 40 pupils participated in the program. In a similar manner, they used a revised version of the data collection instruments and some other additional techniques. The analysis of pre- and post-test responses revealed that even though 4<sup>th</sup> graders had limited STS at the beginning, majority of them had significantly enhance their abilities. They were able to grasp the interactions among the components and even some of the participants showed relatively higher STS like identifying hidden dimensions of the system. Apart from these findings, Ben-Zvi Assaraf and Orion found that there were strong significant correlations ( $r > 0.6$ ) among the pre-test, post-test responses, and students' levels of participation by using the Spearman nonparametric correlation coefficient test. Moreover, there were also medium significant correlation ( $r = 0.5$ ) between their written content evaluation and capability to pinpoint and categorize sound connections between information and details.

These responses were showed similar patterns with their previous study (Ben-Zvi Assaraf & Orion, 2005b) in terms of pre-test results. Nevertheless, the post-test responses diverged in a way that STS of 4<sup>th</sup> graders were more developed than the junior high school students who did not participated in the program. Accordingly, they claimed that some of the lower levels of STSs can be achieved accompanied with appropriate activities and courses. The researchers conveyed that giving daily life examples and providing field trips and outdoor learning environments enabled the 4<sup>th</sup>

graders to make the water cycle more concrete in their minds. Nonetheless, they emphasized that more studies are needed to explore the nature of STSs in detail. As a further study, they recommended that in-depth case studies could be fruitful to improve the literature of systems thinking.

Shepardson et al. (2007) conducted a qualitative study in US to examine pupils' conceptions on watersheds and how their conceptions differ in different grade level and communities. The data was collected from 915 students living in the Midwest, United States. Purposive sampling technique was used by the researchers. Different grade levels ranged from 4 to 12 were constituted the sample of the study. The distribution of the school types was 19% upper elementary, 57% middle school, and 24% high school. In terms of community settings, the locations of the schools were as following: urban schools (16%), suburban schools (24%), and rural schools (60%). A draw-and-explain task called 'The Watershed Task' was prepared to portray conception. Inductive data analysis was employed to explore students' conceptions. Accordingly, four categories were formed based on the students' responses. The four conceptions were as following (Shepardson et al., 2007, p. 560)

- Conception 1: Watershed as a natural and dynamic process consisting of a developed hydrologic cycle.
- Conception 2: Watershed as a natural process containing elements of the hydrologic cycle.
- Conception 3: Watershed as the natural storage of water (i.e., bodies of water—lake or pond).
- Conception 4: Watershed as a human-built facility for storing water (e.g., water stored in a “shed” or “tower”)

Except for Conception 4, the other ones portray a watershed including natural processes. Conception 1 corresponds to a complicated water cycle among the others, but the researchers emphasized that Conception 1 does not refer to the most advanced mental model of a watershed. Conception 2, on the other hand, does not embrace the context of groundwater or runoff. In Conception 3, includes water as stored in lakes or ponds usually between the mountains and water cycle is not depicted as water source. Last, Conception 4 is about man-made water storage buildings.

Chi-square statistics demonstrated that the only statistically significant differences were observed in grade level by Conception 1 ( $\chi^2 = 6.47, p = .039$ ) and community setting by Conception 3 ( $\chi^2 = 9.42, p = .009$ ). This means that upper elementary and middle school students might have an advanced conception on water cycle compared to the high school students. The researchers attributed this to the curriculum was included the concept of water cycle in those grade levels. On the other hand, students living in rural areas had a possibility to hold an advanced conception on the water cycle compared to the others. Apart from these four conceptions, the researchers realized during the study that older students tended to differentiate the water cycle and the watershed but since they do not learn yet the concept of watershed, they split the word as water and shed. Thus, observing conception 4 was more visible among the urban students because they saw some man-made storages in their daily life, whereas conception 3 was held by rural students more since they have possibility to see 'farm ponds' in their agricultural fields. Additionally, majority of the students' responses were limited to the main processes in the water cycle as precipitation, evaporation, and condensation. Adding runoff, groundwater or biospheric components to their conceptions was rare. Based on their drawings and explanations, the researchers concluded that students' drawings as well as conception tended to imitate the visuals available in the textbooks and the other resources. In other words, students did not associate the watershed with their residence areas. Based on these limitations, Shepardson et al. recommended that curriculum developers should tailor adding the concept of watershed into the curricula. Moreover, they also highlighted that further studies are needed to reveal the possible connections between students' understanding and their decision-making processes as well as environmental behaviors.

Two years later, Shepardson et al. (2009) published another qualitative study linked to students' conceptions on the water cycle as a function of grade level and residence area. The data was collected from 1,298 participants living in Midwest, USA. Purposive sampling technique was utilized to increase the variability among the participants. Consequently, pupils whose grade level ranged from 4 to 12; school

types' percentages were 19% upper elementary, 57% middle school, and 24% high school were participated into the study. In terms of community settings, the locations of the schools were as following: urban schools (16%), suburban schools (24%), and rural schools (60%). At the first stage, draw-and-explain technique was used. On the other hand, a conventional water cycle illustration was used without giving hints the names of elements of water cycle. In addition to these, this illustration included the probable human effects on the water cycle. Based on the illustration, it was asked to pupils to explain the figure. Based on the responses, the four categories of students' conceptions were summarized as following (Shepardson et al., 2009, p.1455):

- Conception 1: The Hydrologic Cycle as Water Storage, Transformation, and Transportation with multiple Pathways.
- Conception 2: The Hydrologic Cycle as Water Storage and Transformation.
- Conception 3: The Hydrologic Cycle as a Weather Event.
- Conception 4: The Hydrologic Cycle as an Entity.

Among the conceptions, Conception 1 denotes the most complicated conception in which phase changes, storage, and movement of water are included. In Conception 2, water storage at the surface of the geosphere and main processes in the water cycle (precipitation, condensation, and evaporation) are available. In addition, sun as a power source is also mentioned. Conception 3, as its name implies, is about water cycle in the atmosphere. The most-frequent processes mentioned in this conception is rain. The last conception, Conception 4, is seeing the water cycle a static object like a water source. Chi-square analysis revealed that appearance of Conception 2 was statistically significant compared to the other conceptions among the students ( $\chi^2 = 8.10, p = .044$ ). This result illuminated that pupils tended to ignore the movement of water within the water cycle as streams and rivers. The analysis of the drawings also revealed that students' conceptions were limited to the main processes in the water cycle such as precipitation, evaporation, and condensation. What is more, human effect on the water cycle were not detected in students' drawings as well as in their explanations. In fact, the drawings were not compatible with the topography of their residence areas. The researchers interpreted these finding as students might not be able to correlate the

water cycle phenomenon with their daily life activities. In a similar manner, the students were not able to correlate climate and climate change with the working principles of the water cycle. In the light of their findings, Shepardson et al. (2009) recommended that school curricula should consider these limitations of the students' conceptions and make necessary revisions by means of water cycle, human effect, climate, and climate change as a system rather than including these concepts as 'silos'.

Endreny (2010) conducted a study based on the theoretical framework of Shepardson et al. (2007) aiming to investigate the role of place-based inquiry on urban 5<sup>th</sup> graders' understanding about watersheds. She followed the methods and practices of teacher research. The researcher was the teacher of the students. A total of 33 students were participated in the study. Data sources were pre- and post-concept maps, notebooks, and interview responses of the students. The students visited an urban watershed and also learned concepts in the classroom. The analysis of the concept maps illuminated that more students were able to integrate the processes (i.e precipitation, evaporation) in the water cycle into the watershed compared to the beginning of the program. On the other hand, factors affecting the watershed were not apparent in the concept maps and thus, these factors were asked to elaborate in their interview responses and other written materials. The data analysis revealed that each participant made progress in their unique way. More than 80% of the students exemplified point source pollution, whereas more than 40% of the students stated land use pollution. Majority of the students also included living organisms into their watershed conceptions. The researcher explained that these examples were based on students' outdoor observations at the urban watershed. On the other hand, their drawings contained city elements like roads, vehicles, and houses as well as man-made pollutions. This result was not compatible with the previous findings in the literature (Dove, Everett, & Preece, 1999; Shepardson, Harbor, & Wee, 2005). Unlike this findings, students' perceptions of water drain and run-off were compatible with the findings of Ben-Zvi Assaraf and Orion's work (2005). Apart from these findings, the researcher also reported that majority of the 5<sup>th</sup> graders failed to acquire the concepts given in the classroom context.



In brief, Endreny (2010) concluded that place-based activities enhanced students' learning and help them attributing an emotional response to the place that they visited.

Österlind and Haldén (2007) aimed to explore students' ability to make sense of freshwater pollution. They designed and implemented a six-day program for middle school students. One of the groups participated in the program was selected as case for the study. Students' oral responses during the program, observation notes, and students' written responses were analyzed. The analysis revealed that students failed to grasp the concept of freshwater pollution despite of high level of involvement to the activities both realized as indoor and outdoor. They failed to link theory and practice and take these as two separate unconnected contexts. Especially, students tended to conceptualize the pollution based on their observations and failed to correlate their observations with the concepts (e.g. molecular definition of the pollution) learned in the classroom. Based on their findings, Österlind and Haldén emphasized that students need to be taught to see the connections between theory and practice in an explicit manner.

Another research group focuses on the development of understanding of water in environmental and socio-ecological systems. They included K-12 students (Covitt, Gunckel, & Anderson, 2009; Gunckel K. L., Covitt, Salinas, & Anderson, 2012) as well as pre-service teachers (Gunckel, Covitt, & Salinas, 2018) to the scope of their studies. Covitt and her colleagues (2009) built a curricular framework for promoting *water science literacy* and reported pupils' difficulties developing an understanding of that framework. In their research, they specifically interested in 'understandings necessary for reasoning about water in natural and human-engineered water systems' (Covitt et al., 2009, p.38). In this study, they reported their 'lower anchor research' which was related to the students' conceptions on natural water system and human-engineered one. Before that, they positioned their notion as pupils' understandings are not considered as alternative conceptions that need to be eliminated. Rather, these conceptions can be used to prepare a science instruction in which students could be able deepen their understandings on that subject. They collected data from different

grade levels ranging 3-12. They prepared two instruments compatible with students' cognitive and grade level. The percentages of grade levels of 561 participants were as following: 20.3% elementary students, 34.6% middle school students, and 45.1% high school students. Their report covered the relationship between human-engineered water system and atmosphere, water on land, and water beneath the surface. The highlights of their findings as following:

- Majority of the students explain the water flow based on their observations, yet they failed to integrate the law of conservation to natural water system and follow the water and materials within between observable and hidden parts of system
- They also failed to indicate microlevel and macrolevels in systems (compounds or watersheds)
- Majority of the students in high school were not able follow water and other materials within the context of phase changes and distillation.
- Minority of the students claimed that pollution could also evaporate with water and precipitate on land.
- Approximately one third of elementary students illustrated underground water in man-made silos, whereas 12% of the middle school students and 12% of the high school students included it in their drawing.
- Two thirds of middle and high school students stated that groundwater forms as streams, or lakes beneath the surface. Minority of the students in all grade levels reflected more accurate depictions of groundwater in spaces and cracks in rocks and sediment. Nevertheless, their illustrations became complicated as a function of grade level.
- Some of the middle school student depicted some dots to reveal dirt in the water. The researchers interpreted this phenomenon as pupils identify pollution at macroscopic level such as litter and are not able to see the pollution yet at microscopic level. This response was similar with Österlind and Haldén's work (2007).

- Students in all grade levels were able to aware the human effects on the quality of water as well as its circulation in systems.
- Majority of the students reported that water in their taps is coming from a natural source. Only 20% elementary and 40% high school students were aware of that their tap water are exposed to a treatment before coming from their home. Likewise, 12% of elementary and 25% of middle school students reflected that water is also retreated somewhere like a treatment plant after they use it at home. On the other hand, the percentages were higher (55%) in high school. However, the high school students also claimed that treated wastewater is also 'recycled back' in households and they failed to indicate discharging to a receiving environment.
- Majority of the students presumed that both drinking water and wastewater should be treated; however, a few of them indicated the treatment plants. What is more, they were not be able to differentiate different water treatment plants. The researchers attributed this to as one of the limitations in K-12 program.

Covitt and her colleagues (2009) suggested that exploring students' initial ideas on human-engineered water system might pave the way to define a learning progression about water system in nature and in cities. They reported that pupils had informal reasoning about water systems and their notions are limited to underground pipes and they fail to see the interaction of water supply network with the other systems. Hence, this hinders students to follow water moving in linked systems. To overcome these limitations, they recommended that educators could provide experiences or show models to the students to enhance their learning on water systems in both observable and non-observable aspects.

In another consecutive study, Gunckel, Covitt, Salinas, and Anderson (2012) manifested four levels of achievement in pupils' reasoning pertinent to water and other materials within the water in different subsystems such as atmosphere, geosphere, and human-engineered elements in those sub-systems. They described a learning progression from lower anchor to upper anchor and determined four categories based

on these anchors. They used pupils' submitted assessments as data source and the sample constituted 193 students, 65 from elementary, 65 from middle school students, and 63 from the high school students. There were 17 items in four clusters in the instrument. Every participant from middle school and high school responded items from all clusters, whereas elementary students responded three clusters. Thus, the unit of analysis was determined as set of answers in a cluster from each participant. The features of each level and its elements were given in the table below.

Gunckel et al. (2012) reported only minority of the high school students revealed the characteristics of Level 4. On the other hand, Level 3 was corresponded to 89<sup>th</sup> percentile, whereas Level 2 was in 22<sup>nd</sup> percentile. More than two-thirds of the pupils lied between Level 2 and Level 3. The researchers interpreted this result as minority of the high school students are able to reach in level 4 which is essential for being literate on environmental science. In brief, Gunckel et al. (2012) concluded that pupils' notions on water in environmental systems differs from scientists and this is shaped by students' experiences and daily language. Thus, both scientists and science teachers should be aware of the position of people in decision-making processes in environmental issues. To achieve literate individuals on these issues, our curriculum should enhance students' capability.

**Table 3-5**  
*Level of Achievement and Correlated Elements*

| Level of Achievement                               | Elements of Accounts                                                                                                                                                                                                              |                                                                                                                                              |                                                                                                                       |                                                                                                                                                           | Dependency and Human Agency                                                                                                                                                                             |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                    | Structures and Systems                                                                                                                                                                                                            | Scale                                                                                                                                        | Scientific Principles                                                                                                 | Representations                                                                                                                                           |                                                                                                                                                                                                         |
| Level 4:<br>Qualitative model-based accounts       | Provide multiple, detailed, accurate pathways through environmental systems<br>Account for chemical nature of substances during mixing and moving                                                                                 | Atomic-molecular through large landscape                                                                                                     | Include driving forces (e.g., gravity, pressure)<br><br>Include constraining factors (e.g., permeability, topography) | Interpret constraining factors inferred from representations                                                                                              | Identify limitations to human agency or dependence on environmental systems                                                                                                                             |
| Level 3:<br>Incomplete school science accounts     | Provide multiple pathways through hidden and invisible connections, including human-engineered systems in moderate detail<br>Identify different types of substances in water                                                      | Microscopic to landscape scale                                                                                                               | Put events in order                                                                                                   | Connect representations to three-dimensional physical world                                                                                               | Include human systems as part of environmental systems                                                                                                                                                  |
| Level 2:<br>Force-dynamic accounts with mechanisms | Identify familiar and visible connections, including general connections to human systems<br><br>Water quality is referred to as a function of "good" and "bad" stuff<br>Water is represented only in isolated, visible locations | May refer to smaller particles such as atoms or molecules<br>Broader macroscopic to large-scale focus across familiar and visible dimensions | No driving forces or constraining factors included<br>Identify mechanism<br>Rely on actors or agents                  | Do not infer driving forces or constraining variables<br><br>Include limited (e.g., 2 dimensional) connections from representations to the physical world | Do not recognize limitations of either human agency or environmental systems<br>Portray human systems as operating separately from natural systems but human systems can be impacted by natural systems |
| Level 1:<br>Force-dynamic accounts                 | Water quality is referred to as a function of types of water                                                                                                                                                                      | Limited to macroscopic and immediately visible structures or phenomena                                                                       | Focus on human structures, actions or needs<br><br>No mechanisms for phenomena included                               | No connections from representations to the physical world                                                                                                 | Portray humans as sources and movers of water<br><br>Portray water as serving human needs                                                                                                               |

(Retrieved from Gunckel et al., 2012, p.854)

Havu-Nuutinen, Kärkkäinen, and Keinonen (2011) investigated elementary students' conceptions of water within the context of Science-Technology-Society (STS) perspective. Case study was employed as research methodology. A total of 52 students from grade level of 4 and 5 in a rural school of Finland were participated into the study. Students were requested to record the keywords that came to their mind related to water both before and after the STS training. Additionally, students' pre-drawings were also used as data sources. The pre-responses of the students revealed that they attributed the role of water to human beings by means of domestic and recreational purposes even though these notions were limited. Students in 4<sup>th</sup> grade level also mentioned that water is very important resource for life and there is certain amount of water in our body. On the other hand, 5<sup>th</sup> grade students elaborated living organisms and their water needs compared to the 4<sup>th</sup> graders. After the instruction, students included STS elements and water cycle. Additionally, their perceptions on the interaction in the water cycle began to develop. The researchers also emphasized that students explained the interactions of water from biological and geographical perspectives after STS instruction. Based on their findings, the researchers recommended that teachers should enhance students' learning in STS issues. They should be able to detect students' alternative views so that they could be able to improve students' conceptions.

Havu-Nuutinen, Kärkkäinen, and Keinonen (2018) conducted another research in the similar context as in their previous study. In this study, they explored primary school students' conceptual change after STS instruction. A total of 41 students aged 10-11 participated in an STS instruction related to water use lasted four weeks. The researchers employed case study as a research methodology. Students' written responses before and after the instruction were examined and 10 students were invited for the interview protocol. Students' initial responses revealed that they had already some background knowledge and alternative conceptions which were naïve, detached, and mostly declarative. Moreover, their conceptions were based on daily life experiences. Before designing the STS instruction, these responses were guided. The

researchers were used Halldén's contextualization approach (as cited in Havu-Nuutinen et al., 2018) to examine students' conceptual change. The responses after the STS implementation reflected that students were not fully understand the water concepts in a holistic manner. Yet, they were able to change their initial alternative conceptions. For example, students were able to provide more holistic cause-effect relationships for cyclic nature, water treatment, and groundwater concepts. Nonetheless, only a few of the participants revealed high level of conceptual change.

Forbes et al. (2015) conducted a design-based research to examine 3<sup>rd</sup> grade pupils 'model-based' descriptions for the water cycle. Their study included a framework based on iterative revisions and improvements of regularly used chapter related to water. Moreover, they stated that the framework provided a basis for learning stages for K-12 students. They performed an exploratory research and development for three years to promote and examine 3<sup>rd</sup> grade pupils' model-based descriptions. In this study, however, they provided the results of first year's project. A total of six classrooms in Midwestern state were selected by using maximum variation sampling technique. In these classes, a water module was used as a complementary part to their lectures. Among the pupils, five pupils were interviewed using clinical interview. The results of their study revealed that there were three stages for every learning performances in their framework. Three target concepts (*states of water, water movement, and relationship between water and geosphere*) with five heuristics (*components, sequence, explanatory process, mapping, and principle*) constituted the framework of their study. The major findings of their research were following:

- Water in liquid forms was more frequently mentioned than its solid and gaseous forms
- The reasons for raining were "heavy clouds" and "condensation of water vapor in the air"
- Hidden aspects of water cycle were not stated by pupils
- Pupils model-based descriptions on the water cycle was primarily about the water on land and limited.

- Despite of pronouncing the terms ‘gravity’ and ‘temperature’ in explaining water cycle, their model-based descriptions included only the verbal form of this terms. They failed to give details on the mechanisms in gravity and temperature.

The researchers reached a conclusion based on these findings that science learning environments have an essential role to leverage pupils’ model-based descriptions. In other words, pupils need to be exposed to effective learning opportunities in science classes as well.

Liefländer (2015) studied the role of environmental education in water context. She employed quasi-experimental approach including an EE programme within the context of water and life lasted four days. Pre-test, post-test, and retention questionnaire were used as data collection tools. The study was conducted in a German school and a total of 200 students aged 9-13 were participated into the study. Liefländer also explore the different developmental stages as a function of age. She outlined the findings as following: (1) younger students had a tendency to reveal stronger devotion to nature and pro-environmental attitudes compared to older students; (2) The EE program had a similar effect on both age groups (9-10 and 11-13) in post-test results; however retention analysis showed that the effects of program continued for age group of 9-10 after six weeks; and (3) the level of knowledge enhanced and retained after the programme. Based on the findings, the researcher recommended that for the younger students, educators could focus on increasing the students’ connections to the environment and pro-environmental attitudes through offering direct experiences. For the older students, on the other hand, the researcher suggested that environmental knowledge from multifaceted perspectives or raising awareness and decision-making could be appropriate implications.

In Brazilian context, Ferreira da Luz Culpi and Pereira Alves (2015) inspected the possible effects of didactic approach on students’ conceptions of water footprint. Qualitative research design was chosen, and a total of 35 6<sup>th</sup> grade pupils participated in the study. A survey was prepared by the researchers related to agricultural,



industrial, and domestic use of water. Along with the survey, field diary and written responses were used as data collection tools. Content analysis was used to analyze data. The findings of the study revealed that pupils were more reflective and open to debates on water footprint. The researchers suggested that some media content pertinent to domestic use of water could be used as educational materials in class to promote the STS discussions related to water depletion in Brazil.

#### **2.6.2.4 National Water Studies in the Field of K-12 Education during 21<sup>st</sup> Century**

In Turkish context, Yazıcı and Samancı (2003) investigated 5<sup>th</sup> grade students' understandings of concepts given in Social Science curriculum. They collected data from 44 students from two classes. They administered the instruments after the related chapter taught in the lectures. The findings indicated that more than 90% of the pupils provided no answer related to watershed concept. In terms of misconception, stream (34.1%), climate (34.1%), and precipitation (40.9%) were the concepts that students had alternative conceptions. Based on their findings, the researchers recommended that diagnosing preconceptions of the students have an important role in designing curriculum materials (visuals, diagrams, and other written materials). Thus, these types of studies should be conducted to examine students' preconceptions and alternative conception.

Alkış (2006) conducted a study on precipitation concept of 5<sup>th</sup> grade students. A total of 300 pupils from five schools in Bursa were participated in the study. An instrument composed of 14 items (11 multiple choice, 3 open-ended items) was used as data collection tools. The categories of the questions were as follows: (1) basics of precipitation; (2) precipitation formation; and (3) Seasonal and regional patterns of the precipitation. Pupils' responses were coded as true, restricted, wrong, and blank. The results of this study revealed that some of the pupils held true conceptions in basics of precipitation and its seasonal and regional patterns. On the other hand, more than 40% of the pupils had alternative conceptions on its description, boiling and evaporation,

measurement on the intensity of the precipitation. Alkış concluded that precipitation might be a difficult concept to be grasped by primary school students.

Mecit (2006) conducted a study to illuminate whether 7E learning cycle could enhance the critical thinking skills of 5<sup>th</sup> grade students. She used the chapter of water cycle to examine her hypothesis. A total of 46 students from two classrooms in Sakarya was participated in the study. These classes were named as experimental and control group randomly. Pre-test and post-test were administered to both groups. The analysis of students' responses demonstrated that there was a statistically significant difference between two groups in favor of experimental group  $F(1, 41) = 35.03$ ,  $p = .000$ , partial eta squared = .46). Additionally, there was no statistically significant differences in terms of gender and family income on enhancing critical thinking skills.

Ünal-Çoban et al. (2011) prepared a workshop and reported the change in the participants' conceptions, attitudes, and awareness towards the water. The content of the workshop had three central points as (1) basic concepts of water; (2) water pollution; and (3) efficient use of water. A total of 30 pupils whose grade level ranged from 6<sup>th</sup> to 8<sup>th</sup> grade participated in the workshop lasted five days. Both qualitative and quantitative data were collected as pre-test, post-test, and retention after three months. The findings revealed that the workshop increase students' understanding on water, develop positive attitudes toward efficient water use, and increase consciousness on environmental issues. Quantitative results, on the other hand, supported that pupils' learning were permanent after three months. However, qualitative findings did not support this result. Thus, interview data of 10 children guided to obtain final decision for the retention. Pupils' responses on the interview questions supported the result of quantitative analysis and the researcher concluded that retention was achieved. As a further study, they recommended that control group can be added to the study.

Derman and Yara (2017) worked with high school students to reveal their conceptions on water cycle. A total of 95 high school students (38,9% female; 61,1% male) from south eastern part of Turkey were participated into the study. The median for the age

of the participants were 17. The researchers used word association test and draw-and-explain as data collection tools. Content analysis was employed as data analysis technique. Word association test derived 54 codes in three categories as ‘description of the water cycle,’ ‘stages of the water cycle’ and ‘environment where the water cycle takes place’. The most-frequently-mentioned concepts were following: Water ( $n=61$ ), Cloud ( $n=53$ ), Rain ( $n=70$ ), and Evaporation ( $n=68$ ), whereas photosynthesis ( $n=4$ ) and cyclic nature ( $n=2$ ) were least-mentioned concepts. On the other hand, draw-and-explain task emerged four categories on students’ conceptions on water cycle as following: (a) Level 1: No info/drawing; (b) Level 2: Alternative conceptions with basic drawing (49.4% of the participants); (c) Level 3: Partial knowledge on water cycle (45.3% of the participants); and (d) Level 4: Fully Correct Conception (5.3% of the participants). The researchers interpreted the findings as limited and reported that the students failed to understand evaporation and transpiration processes and to explain the relationships among the components and processes in water cycle as a coherent framework. In the light of the findings, the researchers recommended that context-based real-life approach to this content might be efficient to teach the concept in a meaningful manner. Moreover, using visual aids could also promote their learning.

### **3.2 Water Studies in Literacy Contexts**

Even though this section did not have substantial number of studies as in the literature of water conception, there were some key studies needs to be summarized. These key studies investigated the concept of water within the context of functional literacy (Ewing & Mills, 1994), cultural and historical context (Ben-Zvi Assaraf, Eshach, Orion, & Alamour, 2012) and some aspects that can be considered as critical systems literacy (DeLorme, Hagen, & Stout, 2003; Po, Kaercher, & Nancarrow, 2003)

#### **3.2.1 Functional Literacy**

One of the first pronunciations of the term ‘water literacy’ in the functional literacy context was traced in the works of Ewing and Mills (1994). In their study, they aimed (1) to examine the level of water literacy among university students; (2) to test whether

visual aids could support grasping the concepts of evaporation and condensation in water cycle; and (3) to detect whether there are patterns, if any, among the conceptions of the students pertinent to water cycle. WRKA test constructed by (Mills, 1983) was implemented to 83 incoming college freshmen enrolled in an introductory biology course for non-science majors. Then, the scores of the participants were compared with the one participated in the previous study conducted by Mills (1983). Additionally, pretest and posttest were implemented to the group who enrolled introductory biology course. Instruction was included the visual aids related to the water cycle. ANOVA was performed to evaluate the differences between these two groups. There was no statistically significant difference in water knowledge between these two groups. On the other hand, there was statistically significant differences between pre-test and post-test scores in favor of posttest ( $p < .0001$ ). Moreover, the use of visual descriptions was found to advance understanding of condensation and evaporation. Alternative conceptions that participants had shared similar characteristics with reported ones in the literature. Based the findings, they outlined that even though students recognize the terms, they failed to explain their procedures underpinning those terms. This was labeled by Ewing and Mills (1994) as limited functional environmental literacy. The researchers recommended that visual aids could be one of the promising tools for teaching the concepts efficiently. They also suggested additional studies to compare its effectiveness with the traditional instruction.

Wood (2014) conducted a dissertation on water literacy and citizenship within the context of ESD in UK. She described being water literate as following: “I suggest that a water literate citizen is someone who is informed and knowledgeable about water use and issues and is applying this knowledge to their values and their actions, whether that is achieved actively or subconsciously.” (Wood, 2014, p. 7). She reported that UK people are not aware of how much water they spend; thus, water consumption behavior in UK is not sustainable according to the estimates. Correspondingly, two of the aims of her study was (1) to examine how water literacy of students aged 11-18 interacts with their sustainable water values; (2) to explore the social factors that affect values,

attitudes, and behaviors; and (3) to assess the efficiency of water program in the short term. Her thesis composed of two stages: a literature review on water education and assessing students' water literacy participating a water program in their schools. Thus, mixed-method research design was employed, and data sources were written contents, observations, focus groups, and surveys both before and after the water program. To explore the readiness of students in terms of water literacy in the East Midlands and the social factors that affect water literacy, three groups were investigated (11-12 years & 13-14 years from two secondary schools, and 17-18 years from college). The findings emerged from this investigation guided the researcher to prepare a water program. Consecutively, the changes in students' water values after the program were examined and reported. Besides, a comprehensive discussion was given related to the hinderance of water literacy and citizenship. The findings for the first two research questions illuminated that younger students' perception on saving water was limited to 'water saving tips' which were commonly included in the water contexts in schools. The most frequently mentioned water saving was turning off the taps during brushing their teeth. The sources of this 'water saving tips' were reported by the students as TV/radio, school, internet, family, newspapers/magazines, and post/leaflets. On the other hand, lack of responsibility in water consumption behaviors was also observed in students' responses. The researcher attributed this to (1) the amount of water used in households is unknown by students; and (2) the limited capacity of the students to change household residents' water consumption habits. Additionally, the older students articulated feelings of helplessness towards wide-ranging issues such as leakage.

The researcher also determined some gaps between (1) the awareness of the environmental issues and sense of responsibility towards water saving; (2) value and action; and (3) inability to see the interaction between personal water consumption habits, local, and global water issues. In terms of social factors, the researchers discussed the effects of (1) daily habits and norms of use; (2) attitudes towards

cleaning; (3) other people's behaviors; and (4) technology. The highlights of her findings were summarized below.

- The primary reason for using water efficiently was financial incentives rather than environmental or citizenship concerns despite of not paying bills.
- Majority of the students held the belief that 'I don't think that I used the water as sustainably as I could do'.
- If the students have heard water saving tips from their family, they might have less motivation than to act their own
- The students believed that their water consumption behavior is environmentally friendly but their responses to survey was limited to saving tap water while toothbrushing

To recap, Wood (2014) concluded that water consumption behaviors are composed of daily routines and habits and affected by social factors and technological facilities in their local area. For her third research question which was about assessing the efficiency of the water program that she prepared, post-survey and focus group were used as data source. Three constructs emerged after the program as (1) power and efficacy; (2) the perceived impact and support of community; and (3) sense of responsibility. She interpreted these as possible indicators of *water citizenship development* that could have a potential to accommodate water consumption behavior on sustainable water use. Moreover, she also observed an increase in declarative knowledge of students on water context. Last, she highlighted that education could be one of the indispensable tools to raise water literate citizens. Making hidden use of water 'visible' and revealing the interactions among domestic use, local, countrywide, and global aspects could be the initial steps on the educational agenda. She also added that students' water consumption behavior could not easily changed by enrolling a lecture, but their understandings were enhanced after the water program and this could be a promising result.

### **3.2.2 Critical Literacy**

DeLorme, Hagen, and Stout (2003) investigated the notions of water consumption among the consumers in Florida. Accordingly, a total of six focus group interview was conducted to examine consumers' perceptions on the interactions among the human population growth, development, and water resources to use its implications for environmental education context. Grounded theory approach with theoretical sampling was used. A total of 49 homeowners whose aged ranged from 20 to 87 was participated into the study. The proportion of male and female was kept similar and most of them lived in the area around 12 years. Their responses were examined in five categories as perceptions of population growth and development, perceptions of water quality and quantity, management strategies in water issues in terms of its quality and quantity, and perceived reasons for water conditions. In terms of population growth and development, the participants reported significant increase the number of people, and this brought development and some other facilities, but it costed environmental deterioration in that area. They also shared their notice about the decreases in the water supply as well as water resources such as ponds and lakes. This decrease had an impact on their daily life as well as their recreational activities. Water is more, they also shared their direct experiences that the water quality has changed in their households as well as water resources. They said that swimming in those lakes is not suitable anymore and they saw sometimes dead animals in and around water resources. The strategies of water management were mentioned by the residents were not included themselves and were acquired from outside sources such as direct observations, family members, written sources and mass media. In terms of water consumption behavior, they reported that they were conscious and use water efficiently. They exemplified their monitoring as using water-saving products and using less amount of water in their garden. Their water quality management encompassed using bottled water instead of tap water or using filters in their taps. In their garden, they reported that they started use less the fertilizers. In addition to these perceptions, researchers also asked participants the possible reasons for experiencing these water issues. Their responses

included drought, population growth, developmental effects, absence of planning, inadequate managements of government, and residents' misuse of water. What is more, they elaborated the reasons for residents' misuse of water as apathy, social standards among neighbors related to garden essentials such as green laws, old habits; and having no educational background on water issues. To solve these problems, they proposed several solutions such as revisiting regulations including prices to prevent water loss; using technology for reusing/recycling water, desalination of ocean water, and limiting outdoor use of water like in the gardens. while they were mentioning those solutions, they added that some of these could not be possible to implement due to various reasons. Last, the participants delivered five messages for an environmental awareness campaign as (1) underlining the financial benefits of water management; (2) increasing residents' self-efficacy towards their effects of efficient use of water; (3) increasing awareness about the value of water for life; (4) preparing messages in different languages that residents speak; and (5) keep the message simple so that everyone engages to read it. The possible types of delivery were listed as (1) attaching it to the water bills; (2) focusing this topic on local media; (3) simple electronic sources like web sites; (4) integrating this context to formal education; and (5) residents' collaborations. As a recommendation for further studies, the researchers proposed that this research can be broaden by including all the stakeholders in a water issue besides the residents of an area.

Po, Kaercher, and Nancarrow (2003) reviewed the literature on wastewater reuse after treatment in both international and Australian context. The aim of this review was to explore the factors that could interact with wastewater reuse among societies. They reported some projects achieved both in global and Australia context. The list of the factors was given as following (Po, Kaercher, & Nancarrow, 2003, s. 14):

- Disgust or “Yuck” factor;
- Perceptions of risk associated with using recycled water;
- The specific uses of recycled water;
- The sources of water to be recycled;
- The issue of choice;



- Trust and knowledge;
- Attitudes toward the environment;
- Environmental justice issues;
- The cost of recycled water;
- Socio-demographic factors.

Po et al. (2003) highlighted that despite of appreciating its importance, there is still a need for further social research to comprehend the sources of people's perceptions and the psychological constructs having a role in wastewater reuse consumption behaviors. While they were conducting this review, they found that Ajzen's Theory of Planned Behavior could provide a basis for understanding the variables that might explain readiness of the public to use of treated wastewater. However, they also reported that its usefulness should be examined.

Venckute et al. (2017) studied to make an approximation for water footprint of pupils. They administered two questionnaires to 82 participants aged 12-15. The result illuminated that daily water use of a regular pupil is  $3223 \pm 830$  liters. Their hidden use of water is much higher than the direct use of water. Among the hidden use of water, food (84.4%) and clothing (6.4%) were the first two elements. What is more, meat had the biggest percentage (39.6%) to their overall water footprint. In terms of direct use of water, they spent 264 liters per day regardless of their gender. Most of the direct use of water was taking shower. Based on the results, the researchers concluded that pupils spent too much water and this needs to be regulated through the educational activities.

Amahmi et al. (2019) intended to assess the current status of water in Moroccan curricula for elementary and middle school pupils. They reported that despite of having positive attitudes towards water, their attitudes were not compatible with their water consumption habits. The responses to the survey items illustrated that pupils' knowledge was limited. Among the pupils, 45% of them were conscious about water depletion on Earth. In terms of water consumption behaviors, more than two-thirds of the pupils had unsustainable water consumptions. Based on the findings, the researchers concluded that there are incompatibilities among the knowledge, level of conscious, and water consumption habits. Therefore, they were suggested that value-

based water curriculum accompanied with proper outdoor activities might have a potential to change pupils' unsustainable water consumption habits to sustainable ones. Moreover, they also emphasized that cultural and religious beliefs might have a role in water-related chapters in terms of water conservation, sanitation, and hygiene. They also highlighted that increasing awareness of adults should be also considered.

### **3.2.3 Cultural Literacy**

Taiwo et al. (1999) conducted a study in Botswana context to portray pupils' perception on the water cycle. The sample was included three different settlement areas such as urban, suburban, and remote area dwellers. The researchers used survey method and collected both quantitative and qualitative data. A total of 888 children enrolled from 4<sup>th</sup> to 7<sup>th</sup> grade levels were participated into the study. The alternatives in the instrument were aimed to detect whether pupils had (1) scientific, (2) pseudo, or (3) cultural-based knowledge on cloud formation, rainfall, and rainbow formation. The pilot study was conducted with 40 students and the reliability of the 10-item test instrument was calculated as 0.86. Data were collected by the four data collectors. A total of 384 pupils were individually interviewed to acquire in-depth information for their choices on the instrument. Analysis of variance (ANOVA) was used to evaluate whether significant differences exist in the subjects' perception of the water cycle according to their grade level and school location. In terms of grade level, 7<sup>th</sup> grade pupils showed the best performance compared to the other grade level participants. In terms of socio-cultural environment, no significant differences were found by means of gender. The remote area dwellers had statistically significant greater performance or 'coloration' in their understanding of the water cycle in terms of socio-cultural elements compared with the others. On the other hand, the analysis of the interviews reflected that students' understanding of the water cycle was not clear in their minds. Their perceptions were under the influence of their cultural beliefs as well as pseudo-scientific knowledge. To exemplify, some pseudo-scientific knowledge that they had on cloud formation were "Clouds are packets of water swept into the sky by wind", "Water vapour turns into ice to form clouds.", and "The sun boils the water in the dam

and causes it to form clouds” (p.421). As a recommendation, Taiwo et al. (1999) proposed that curriculum developers should take into account pseudo-scientific knowledge that students have so that meaningful learning would enhance.

Ben-Zvi Assaraf et al. (2012) investigated how cultural differences might interact with pupils’ ‘spontaneous models’ of the water cycle. They compared two groups of 4<sup>th</sup> graders. One of the groups was Jewish living in province, whereas the other group was from native Bedouin community. This native community has no water distribution systems; thus, they either rely on natural water resources around them or they used water brought by trucks to their area. What is more, children in Bedouin community are also labor in their own agricultural areas and stockbreeding in which they interact with water. On the other hand, weather events affect their daily life more than the children living in urban area since their residence have neither road nor vehicles. Based on these unique characteristics, the researchers assumed that students from Bedouin community could have unique mental models on water cycle. Ben-Zvi Assaraf et al. described spontaneous models as created by experiential constructs used impulsively, whereas non-spontaneous models are composed of scientific knowledge. They articulated that spontaneous models are ‘deeply rooted’ than non-spontaneous models and culture might have a role in shaping spontaneous models. Nevertheless, the curriculum of these two communities is same. They enroll same courses and learn same concepts in their schools. A total of 72 students were participated in the study. Three data collection tools were used as repertory grids, drawing, and open-ended interviews. During the interview, the participants were allowed to explain what they draw.

The analysis revealed that participants from Bedouin community have more comprehensive and genuine mental models than Jewish urban students, included religious aspects and indicated relationships between the sub-systems (Ben-Zvi Assaraf et al., 2012). The responses of both two groups were examined in four categories. The first category was about the reasons for raining. Vapors, religious explanations, and cloud formation were stated by the 4<sup>th</sup> graders related to the source

of rain. While students from Jewish community use religious reasons when they had no scientific explanation, Bedouin community used religious aspects in addition to the scientific knowledge. Moreover, both groups had misconception related to the cloud formation as cloud is an entity that fills out with water. The second category was related to the water movement in the geosphere. Unlike the similar responses during the interview, the analysis of the drawings demonstrated that more Bedouin community students included items related to the geosphere such as penetration, groundwater, and surface flow. Two primary models were detected in this category as water movement on the surface and penetration and underground flow. In these categories, more Bedouin students included interactions between the Earth systems and geosphere. The third category was 'water uptake by plants' within the context of the water cycle. Similar with the previous categories, Bedouin students illustrated plants in their drawing and statistically significant difference was found between the drawings of the two groups ( $p < 0.001$ ). At this category, there were two mental models as (a) water uptake directly from rain, and (b) water uptake through the soil. The last category was human aspect in the water system. Once more, Bedouin students included human aspect more than their urban peers in general. Two sub-categories were emerged from the two groups' responses (1) humanity as a consumer and (b) humanity as a part of water system. The Bedouin community students tended to see themselves as a part of the water system in their environment. Based on these findings, the researchers highlighted that the differences emerged from these groups could be related to their cultures and daily life experiences. For example, the category that Jewish students had better than the Bedouin children was related to the water uptake from rainfall and Ben-Zvi Assaraf et al. (2012) attributed this difference to no observation related to rain in desert. After all, Bedouin students' residence area is not a rainy area due to being in a desert. Hence, Jewish students living in town have more observations on raining. Thus, even though all the participants had the same curriculum in their schools, their spontaneous models differed based on their cultural differences. On the other hand, alternative conceptions that Jewish students held were compatible with the literature related to the water context in K-12 education. To

conclude, Ben-Zvi Assaraf et al. (2012) declared that curriculum developers should take into account the interactions among the water cycle, local environment, and cultural aspect. They recommended that outdoor learning as well as cultural exchange opportunities could provide basis for understanding the water system as a whole.

Nam (2012) reviewed the study of Ben-Zvi Assaraf et al. (2012) by interpreting 'spontaneous mental model' pertinent to cultural knowledge of Bedouin pupils in water context. Nam claimed that cultural knowledge accompanied with the history has potentially an effect on children's mental models related to the Earth systems. She believed that Bedouin students' capacity to grasp working principles of water system as a sub-system of the Earth system and change in water resources potential related to climatic factors were culturally inherited to them. Similarly, Korean students have a potential to understand the water system based on their rich culturally inherited knowledge. She stated that her level of knowledge was affected by her culture inherited from her parents. She defended the ideas that even though ancient Korean people did not have procedural knowledge on the Earth systems' working principles, they could be able to infer that a system reacts changes even they are too small. Their inferences were mainly based on their cultural knowledge as well as their daily life observations. Nam highlighted that water has many other meanings in her culture besides its natural forms. For instance, water can sometimes indicate some sentiments like sadness and value since their ancient people used creeks and other surface waters for travel and family meetings. Nowadays, the majority of the children in her culture live in the cities and this makes students' interactions with the nature limited. Thus, the multiple meanings of water are started to disappear. In fact, majority of the students do not even know where their tap water comes from compared to their previous generations. Nam contended that the way of 'western science' learning might weaken nations' cultural knowledge on the nature. She stated that spontaneous mental models of Bedouin pupils did not refer to an opposition of scientific models. Relatively, they were co-existed with the scientific knowledge that they learned in the school. She criticized that some of the students' perceptions in science education are being interpreted as pseudo-

scientific knowledge and/or alternative conception that needs to be eliminated. She also recommended two implications. The first one covers a holistic understanding of the natural system including children's cultural and historical background because these might bring an essential data to enhance children's perceptions related to the natural systems. The other one is about taking into account children's beliefs on the man-nature interactions rooted from their traditions. In this way, we might be able to reduce conflicts in students' minds pertinent to western science and their cultural knowledge. To sum up, the focal point of the water studies in K-12 Education was knowledge of the learners. Although these studies provided valuable contributions, there is a need to study the notions of the cultural perspective as well as other construct that might be interacted with students' conceptions on water system.

## CHAPTER 4

### METHODOLOGY

*“She gave me water – gave me- she gave me water!”*

*(Hunchback of Notre Dame, 1982)*

The purposes of this study are to suggest an alternative definition for systems literacy, to portray the systems literacy of children who completed middle school education in the water system context, and to identify possible components of systems literacy. This chapter covers the design of the study, its participants, data collection, data analysis procedures, and trustworthiness of the study.

#### **4.1 Design of the Study**

In this study, two different research, conceptual research and empirical research, were employed to complete a research cycle and provide an alternative framework for *systems literacy*. In this section, both conceptual research and empirical research were introduced and the rationale for choosing methodologies specific to this dissertation were provided.

##### **4.1.1 Conceptual Research**

As emphasized by Meredith (1993), the cycle of research is an iterative procedure in which descriptive models are evolving to conceptual framework that needs to be verified, revised, or invalidated until they are named as theories. In this cycle, Meredith claimed that conceptual research method, which is primarily based on description and explanation, could be regarded as an integral part of research cycle and omitting this part could decrease external validity of research conclusions as well as their corresponding relevance to specific area of research. Meredith (1993) explained the purpose of the conceptual research as following: “They lead naturally to synthesizing

previous research, thus building on earlier studies, and depend heavily on real-world description, thereby serving as a check on the external validity of our research findings” (p.11).

There are seven types of conceptual research methods under the three sections as *conceptual models*, *conceptual frameworks*, and *theories* (Meredith, 1993). Within the context of the study, *philosophical conceptualization* and *conceptual systems* were employed as conceptual research method compatible with the purposes of the study. Philosophical conceptualization under the section of *conceptual models* mainly combines several studies based on the similar theme, compare similarities and differences, and extends the studies in a sense. For instance, a researcher could be either accommodate all the concepts or constructs or add further concepts or propositions when necessary (Meredith, 1993). In this study, philosophical conceptualization was used to provide an alternative framework for systems literacy by (1) comparing some of the context-based literacies such as scientific literacy, environmental literacy, sustainable literacy, and systems literacy and (2) adding further concepts, constructs and propositions to the present conceptual frameworks of systems literacy. In this way, the researcher of the study formed a conceptual model for systems literacy.

If a conceptual model contains different concepts/constructs within a network of propositions, then it could be named as a conceptual framework (Meredith, 1993). Conceptual frameworks are pre-theories having a potential to provide a basis to a theory. They enable the researchers to grasp the nature of the interactions as well as provide hypotheses to validate, revise or refute. To promote the explanatory power of conceptual model of the present study, conceptual systems under the section of *conceptual frameworks* were also employed by the researcher. The conceptual system constructed by the researcher was given under the chapter of findings.

As to construct valid theories, these models and frameworks needs to be empirically tested and provide reiterations within the research cycle (Meredith, 1993).



Accordingly, this study included an empirical research to test the conceptual framework constructed by the researcher. Based on the empirical findings, the alternative framework of systems literacy in water system context might undergo some revisions to complete the research cycle and provide implications for the further studies. In the next section, the details of empirical research were outlined.

#### **4.1.2 Empirical Research**

Every research design is attributed to different philosophical worldviews in the literature (Slife & Williams, 1995). In this study, qualitative research design as an empirical research was conducted based on *pragmatism*. Specifically, the researcher of the study used the pragmatic notions of Merriam (2009), Merriam and Tisdell (2016), and Patton (1985, 2002). Among the qualitative research methodologies, multiple case study was chosen. This section summarizes the rationale for selecting qualitative research design and multiple case study.

As Merriam and Tisdell (2016) highlighted, there are a lot of approaches to describing what makes a research qualitative. According to them, qualitative research paradigm covers the systems of approaches and practices being sufficient for data collection and analysis. The researchers who adopt this paradigm aim to discern individuals' interpretation of their experiences, perception of their environment, and the way of making sense based on these two (Merriam & Tisdell, 2016). Patton (1985) mentioned the aim of the qualitative research as following:

... is an effort to understand situations in their uniqueness as part of a particular context and the interactions there. This understanding is an end in itself, so that it is not attempting to predict what may happen in the future necessarily, but to understand the nature of that setting (p.1).

Compatible with the explanations of Merriam (2009) and Patton (1985), this study aimed to explore how individuals perceive their environment in the context of the water system and how they make sense based on their perceptions as well as their background knowledge. At this point, qualitative research design has a potential to

provide an in-depth understanding for the nature of systems literacy as well as its possible components in water system context. Moreover, the characteristics of collecting multiple forms of data in qualitative research (Merriam & Tisdell, 2016) enables the researchers to explore the readiness of the participants' systems literacy in a comprehensive manner. Correspondingly, qualitative research was selected of the study.

#### **4.1.3 Case Study as a Specific Methodology**

Case study is one of the qualitative research methodologies that constructed on differing philosophical frameworks (Yazan, 2015). Among them, Merriam and Patton's description of the case study was preferred compatible with the philosophical framework of this dissertation. Merriam and Tisdell (2016) highlighted that "the single most defining characteristic of case study research lies in delimiting the object of study: the case" (p.38). According to them, a case can vary from a single person to a particular group of people as well as it can be a specific program. The key point here is that the unit of the analysis must be a "bounded system" to be named as qualitative case study. Merriam and Tisdell did not made a specific distinction between the case and the unit of the analysis. Correspondingly, the unit of the analysis/the case of this dissertation were determined as "student". The context, on the other hand, was identified as participants' systems literacy in water context.

Since the unique characteristics of four distinctive cases, the researcher of the study preferred to use multiple case study. In the *Encyclopedia of Case Study Research*, multiple case study was defined as "... refers to case study research in which several instrumental bounded cases are selected to develop a more in-depth understanding of the phenomena than a single case can provide." (Chmiliar, 2010, p.583). Within the context of the study, four bounded cases were selected to explore participants' systems literacy in water context. Each case was chosen based on pre-determined criteria and these criteria were set to reveal unique characteristics of the cases. This enabled the researcher to obtain in-depth information about the context. These criteria were given

in the subsequent section with their rationale. Additionally, multiple case studies need inherently comparisons among the cases to scrutinize important similarities and differences as well as the potential elements that illuminate those differences (Patton, 2015). Accordingly, cases of this study were suitable to be compared in terms of similarities and differences of the cases as well as to examine the possible factors that constitute systems literacy in water context. Table 4.1 provides a summary of the research questions, types of research and its specific research methodologies.

**Table 4-1**

*Data Collection Tools and Related Categories in Systems Literacy in Water Context*

| <b>Research Question</b>                                                                                                          | <b>Types of Research</b> | <b>Research Method - Methodology</b> |                                 |
|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------------------|---------------------------------|
| 1)What is systems literacy?                                                                                                       | Conceptual Research      | Conceptual Models                    | Philosophical Conceptualization |
| 2)What is the alternative framework of systems literacy in water system context?                                                  | Conceptual Research      | Conceptual Frameworks                | Conceptual Systems              |
| 3)What are the possible factors that might interfere with systems literacy in water context?                                      | Empirical Research       | Qualitative Research                 | Multiple Case Study             |
| 4)What are the readiness levels of children completing middle school degree in terms of systems literacy in water system context? |                          |                                      |                                 |

## **4.2 Participants of the Empirical Research**

In this section, selection of the participants and description of the participants were given. In the selection of the participants, sampling strategy and general information about the participants -or cases- of the study were provided.

#### **4.2.1 Selection of the Participants**

Merriam (2009) reported that purposive sampling technique is used in general in qualitative studies. As stated by Patton (2015), even though generalization is not possible in small samples, purposefully selected ones have a great potential to provide some insight(s) for the further studies since they enable us to acquire in-depth information of specific cases. They are called information-rich cases (Merriam & Tisdell, 2016; Patton, 2015). Within the context of the study, qualitative purposeful sampling was used since it was not intended to generalize the findings of the study to any population. Instead, “informative” students were planned to be selected because it was aimed to understand the systems literacy of the students in water context in-depth and identify possible components of systems literacy. Accordingly, selection criteria were set before determining the cases who have a potential to maximize the possibility of selecting “informative” cases.

Patton (2015) suggested several steps for how to conduct purposeful sampling. At first, researchers must decide which selection criteria are important for choosing the cases. These criteria should be compatible with the aim of the study and helpful for finding “informative” cases. While listing the criteria, researcher should also provide their rationale for these selection criteria. After that, they should specify which purposeful sampling strategies that they chose. Patton (2015) identified 40 purposeful sampling strategies classified into eight categories.

The selection criteria were determined as (1) being 9<sup>th</sup> grade student; (2) enrolling in different types of high schools; and (3) childhood residence before the high school. One of the purposes of the study was to portray the systems literacy of children who completed middle school education in the water system context. Parallel with the purpose of the study, participants who completed middle school education was selected. All participants were 9<sup>th</sup> grade students at the fall semester. The reason for choosing 9<sup>th</sup> graders was based on my prior observations during site visits before data collection. I explained the rationale in detail under the section of “Pilot Study”.

For the selection of the schools, I purposefully included different types of high schools. In the sample of the study, I included both public and private high school students. I also included cases from science high school and social science high school to provide variability among the cases. Last criterion for the sampling was their childhood residence before high school to determine whether students' systems literacy may interact with their everyday experiences in their hometown. I delimited childhood residence in terms of water context since systems literacy was traced in water context in this study. Accordingly, participants were chosen living in different places such as coastal city, inland city, or any waterfront area (i.e., riverside) to examine whether their systems literacy interacted with their interactions with water or not and how these interactions might shape their systems literacy in water system context. In short, there were three selection criteria and they determined by the researcher before the data collection.

Among the purposeful sampling strategies, *matched comparisons* was selected which belongs to the *comparison-focused sampling* category. Matched comparisons was defined by Patton (2015, p.405) "Studying and comparing cases that differ significantly on some dimension of interest to understand what factors explain the difference". Within the context of the study, four cases were differing in the types of the high school and childhood residence before the high school. Two participants were from two different public high schools, whereas two of the other participants were from two different private schools. Besides, two of the participants were living in inland city, whereas the other participants were coming from seaside and riverside. These selection criteria were determined to understand their potential to explain the differences in participants' systems literacy in water context.

#### **4.2.2 Descriptions of the Participants**

In this section, participants were introduced to the readers. Along with three selection criteria given above, their gender, achievement level based on their percentile in the national high school entrance exam scores, some indicators for parental socioeconomic

status, their notion of sustainable development, and extracurricular activities that they participated in were collected to provide thick description for them.

As reported in the Turkish Ministry of Education (2018), while socioeconomic status is positively correlated with achievement level, it has also an indirect effect on students' academic background and sociocultural environment. Within the context of this study, parental socioeconomic status was included to examine its potential, if any, on students' systems literacy in terms of functional, cultural, and critical manner. During the data collection, it was not asked students directly their parental socioeconomic status. Instead, their national high school exam scores (Thomson, 2018), parental occupation (Galobardes et al., 2006) and parents' level of education (Aarø et al., 2009) which are three of the potential indicators for parental socioeconomic status were collected. Furthermore, participants' notion of sustainable development was also asked since sustainable development and principles of systems science are correlated concepts (Hjorth & Bagheri, 2006). Last, extracurricular activities that students participated in were also asked. I delimited the term of extracurricular activities with the keywords "water" and "system" which are related to the purposes of the study. The summary of these data was summarized in [Table 4-2](#).

### **4.3 Data Collection of the Empirical Research**

In this section, data collection tools and data collection procedures used in empirical research were reported. As simplified by Merriam and Tisdell (2016), data forms like words and/or phrases are called as qualitative data, whereas numbers are considered as a form of quantitative data. Within the context of the study, qualitative data were collected from the cases based on multiple data collection tools. In addition to qualitative data, quantitative data were also produced to organize and visualize some of the qualitative data. Categories of systems literacy were formed through the data collection tools which was summarized in [Table 4-3](#). Please note that all data collections tools were complementary to each other. That is to say, each data collection tool did not reveal fully the codes within the categories. For instance, there are five

codes within the category of “General Characteristics of Water” in FSL. While two of them were included in the conception test, the remaining three categories may emerge either during the interview or the drawing task.

#### **4.3.1 Data Collection Tools**

In this section, data collection tools were introduced. Accordingly, conception test, drawing tasks as researcher-generated documents, reading task based on a real story, and semi-structured interview were introduced. Validity evidences for the data collection tools will be given under the section of “Pilot Study”.

##### **4.3.1.1 Conception Test**

Conception test involves 10 question sets in the form of four-tiered multiple-choice items to explore students’ system literacy in water context. Each question set was composed of four sub-questions. The first and third questions were related to content knowledge and reasoning for students’ content knowledge. The second and fourth questions were related to their level of confidence rating. Some of the questions were adopted by Schaffer’s study (2013). In the conception test of this study, the first four set of questions (Q1- Q4) were adopted from Schaffer (2013). They were transformed into four-tiered test, added a blank alternative for the first and third sub-questions for each set. Further alternatives to the questions (Q1 and Q3) were also added based on the findings of the pilot study. The other questions were used as it was in the original version (Q1 and Q4). The rest of the question sets were written by the researcher based on the findings of the pilot study. The aim of the test was to classify students’ knowledge as (a) scientifically correct; (b) false negative; (c) false positive; and (d) alternative conception/ misconception. False negatives refer to the incorrect responses based on correct, scientific explanations (Hestenes & Halloun, 1995). False positives, on the other hand, refer to the correct responses based on an incorrect explanation (Hestenes & Halloun, 1995). The conception test and its answer key were available in Appendix A. [Table 4-4](#) listed the misconceptions and correlated categories of FSL in water context.

**Table 4-2**

*General Profile of the Participants*

| Participants and Birth Year | National Entrance Exam Score (x/500) | Percentile       | Types of School            | Location of the House | Parent's Occupation                                     | Participation to Extracurricular Activities                                                |
|-----------------------------|--------------------------------------|------------------|----------------------------|-----------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------|
| Eren (2005)                 | 500                                  | 1 <sup>st</sup>  | Science High School        | Inland                | Father: Doctor<br>Mother: Engineer                      | - Systems Science Seminar<br>- SD goals Seminar<br>- Physics Project<br>- Science Olympiad |
| Cansu (2003)                | 421 (TEOG)                           | 18 <sup>th</sup> | Social Science High School | Village               | Father: Worker<br>Mother: Cook                          | - Waste Collection Event in Kızıllmak<br>- Water Footprint Seminar                         |
| Ahmet (2005)                | 438                                  | 6 <sup>th</sup>  | Private School             | Seashore              | Father: Academician in Faculty of Law<br>Mother: Lawyer | - Videos related to Water Footprint                                                        |
| Deniz (2005)                | 390                                  | 15 <sup>th</sup> | Private School             | Inland                | Father: Banker<br>Mother: Environmental Educator        | -Extra Science Courses for high achiever of the school                                     |



**Table 4-3***Data Collection Tools and Related Categories in Systems Literacy in Water Context*

| <b>Data Collection Tool</b>        | <b>Elements of Systems Literacy</b> | <b>Categories of System Literacy</b>                                                                                                                                                                                                                                                                                                                          |
|------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Conception Test                    | Functional Systems Literacy         | General Characteristics of Water<br>Power Sources of Water Cycle<br>Relationship between the Earth Systems                                                                                                                                                                                                                                                    |
| First Drawing Task                 | Functional Systems Literacy         | General Characteristics of Water<br>Power Sources of Water Cycle<br>Components and Processes of Water Cycle<br>Relationship between the Earth Systems                                                                                                                                                                                                         |
| Second Drawing Task                | Cultural Systems Literacy           | Components of Local Water System<br>Relationship between LWS and (Sub)systems                                                                                                                                                                                                                                                                                 |
| Reading Task Based on a Real Story | Critical Systems Literacy           | Dynamic Nature of Water System<br>Causal Dynamics and Feedback Loops<br>Complexity of Water System                                                                                                                                                                                                                                                            |
| Semi-structured Interview          | Functional Systems Literacy         | General Characteristics of Water<br>Power Sources of Water Cycle<br>Components and Processes of Water Cycle<br>Relationship between the Earth Systems                                                                                                                                                                                                         |
|                                    | Cultural Systems Literacy           | Components of Local Water System<br>National Water Resources<br>Relationship between LWS and (Sub)systems                                                                                                                                                                                                                                                     |
|                                    | Critical Systems Literacy           | Dynamic Nature of Water System<br>Causal Dynamics and Feedback Loops<br>Evolutionary Processes in the System<br>Complexity of Water System<br>Beliefs about Water Use<br>Self-efficacy towards Efficient Water Use<br>Motive Concern<br>Action Strategies for Efficient Water Use<br>Emotional Response<br>Motivational Orientation for Sustainable Water Use |

#### **4.3.1.2 Researcher-Generated Documents**

Merrim and Tisdell defined the researcher-generated documents as (2016, p.174) “...are documents prepared by the researcher or for the researcher by participants after the study has begun. The specific purpose for generating documents is to learn more about the situation, person, or event being investigated.” Within the context of the study, two drawing tasks were requested from the participants to acquire visual documents for triangulating data of their systems literacy in water context.

All drawing tasks were completed in the first session of the data collection. The first drawing task was about drawing a water cycle. Second drawing was drawing the local water system that participants live in. When the drawing part completed, the researcher asked further questions related to their drawing. In both drawing sessions, students are allowed to modify their drawing whenever they want. The drawing tasks, their content, aim, and the corresponding types of systems literacy were summarized in [Table 4-5](#).

#### **1.2.1.1 Interviews**

Merriam and Tisdell (2016) emphasized that interview data is a useful data forms to get in-dept information in case studies. Patton (2015) described the aim of interviews as to get information from people that we cannot directly observe. As the purposes of this study included unobservable constructs, the primary data collection tool was semi-structured interview. Participants’ responses on the other data collection tools were also elaborated via interviews. This enabled the researcher to acquire in-depth information of students’ systems literacy in water context.

**Table 4-4***Conception Test Question, Content of The Misconception, and Categories in FSL*

| <b>Question</b> | <b>Content of the Alternative Conception / Misconception</b> | <b>Categories/Codes in FSL</b>                                      | <b>Source</b>                                                |
|-----------------|--------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------|
| Q1              | Storage of most of the water on Earth                        | General Characteristics of Water- Quantity of Water                 | Schaffer, 2013                                               |
| Q3              | Change in total amount of water on Earth                     | General Characteristics of Water- Cyclic Nature                     | Schaffer, 2013                                               |
| Q7              | Starting/ending point of the water cycle                     | General Characteristics of Water- Cyclic Nature                     | Pilot Study                                                  |
| Q2, Q5, Q8      | The power sources in the water cycle                         | Power Sources of the Water Cycle                                    | Schaffer, 2013 (Q2)<br>Dutton, 2015 (Q5)<br>Pilot Study (Q8) |
| Q4              | Cloud Formation                                              | Relationship between the Earth Systems- Hydrosphere- Atmosphere     | Schaffer, 2013                                               |
| Q6              | Cloud Formation                                              | Relationship between the Earth Systems- Hydrosphere- Atmosphere     | Pilot Study                                                  |
| Q9              | The relationship between global warming and water cycle      | Relationship between the Earth Systems- Hydrosphere- Anthroposphere | Pilot Study                                                  |
| Q10             | The relationship between water cycle and climate change      | Relationship between the Earth Systems- Hydrosphere- Anthroposphere | Pilot Study                                                  |

Semi-structured interview which is one of the type of *interviews by structure* (Merriam & Tisdell, 2016) was chosen. Semi-structured interviews presumed that every individual has its own understanding and express these understandings in their own way. Accordingly, the questions are constructed as open-ended considering these variations among the participants. It also includes structured questions because there is also some specific information that needs to be collected from the participants. This structure guided the researcher to monitor the flow of the interview based on the responses of the participant. There were four phases in the interview given in the subsequent sections.

#### **4.3.1.2.1 Phase 1: Interview on First Drawing Task**

In this phase, semi-structured interview was conducted after completing the first drawing task which was about the water cycle. As given in [Table 4-5](#), the aim of the first drawing task was to examine students' diagram on water cycle to portray their FSL in water context. To provide in-depth information on their FSL, the first phase of the interview was constructed. There were four structured interview questions that guided the interview. Some other sub-questions were added during the interview based on the participant's responses. These four questions, their aims, and their correlated categories by means of FSL were given in [Table 4.6](#).

#### **1.2.1.1.1 Phase 2: Interview on Second Drawing Task**

In this phase, the notion about their local water system was elaborated after completing the second drawing task. As given in [Table 4-5](#), the aim of the second drawing task was to examine students' diagram on local water system to depict their CUSL in water context. To acquire in-depth information on their CUSL, the second phases of the interview was prepared. There were eight structured interview questions that guided the interview. Some other sub-questions were added during the interview based on the participant's responses. These eight questions, their aims, and their correlated categories by means of CUSL were given in [Table 4.7](#).

**Table 4-5**

*The Drawing Tasks, Their Contents, Aims, and Corresponding Types of Systems Literacy*

| <b>Drawing Task</b>                                  | <b>Aim of the Task</b>                                                                                                                                                                                                                                                                                                                                                                                 | <b>Types of Systems Literacy</b> | <b>Source</b>                  |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------|
| 1 <sup>st</sup> Drawing Task<br>(Water Cycle)        | <p>To examine students' diagram on water cycle to portray their functional systems literacy in terms of indicating</p> <ul style="list-style-type: none"> <li>- cyclic nature of the water</li> <li>- power sources of the water cycle</li> <li>- components and processes in the water system</li> <li>- relationship between the Earth (Sub)Systems</li> </ul>                                       | Functional Systems Literacy      | Ben-Zvi Assaraf & Orion (2010) |
| 2 <sup>nd</sup> Drawing Task<br>(Local Water System) | <p>To examine students' diagram on their local water system to portray their cultural systems literacy in terms of indicating</p> <ul style="list-style-type: none"> <li>- Components of local water system</li> <li>- Components and processes in water supply network</li> <li>- Components and processes in sewerage system</li> <li>- Relationships among local and global (sub)systems</li> </ul> | Cultural System Literacy         | Pilot Study                    |

#### **4.3.1.2.2 Phase 3: Interview on Critical Systems Literacy in Water Context**

To provide in-depth information on the critical systems literacy in water context, semi-structured interview protocol was constructed by the researcher. The types of the interview questions were mainly experience and behavior questions, opinion and values questions, feeling questions, and knowledge questions (Merriam & Tisdell, 2016) congruent with the purposes of the study. There were 15 interview questions that guided the interview process. Some other sub-questions were added during the interview based on the participant's responses. These 15 questions, their aims, and their correlated categories by means of CRSL were given in Table 4.18.

#### **4.3.1.2.3 Phase 4: Interview on Reading Task Based on a Real Story**

In the last part of the second session, a real story was given to the participants. Accordingly, the researcher asked some questions related to the story to collect some indicators related to their critical systems literacy. Reading task was revised by the researcher based on a local story available online (Ayman, 2016) about the effects of climate change on the water system.

The issue of climate change in that story included some hints about dynamic nature of the water system, and the layers of complexity in a narrative and implicit way. After simplifying and revising the reading task, semi-structured interview protocol was prepared. The interview questions were written to reveal participants' notion on the dynamic nature of the systems, causalities and feedback loops, and complexities in the water system. The reading task was given in Appendix B. Interview questions and their categories were given in [Table 4.9](#).

**Table 4-6***Interview Questions, Aims, and Categories of FSL – First Phase*

| Translation of the Interview Questions                                                                                                                                                                                                                   | Aim of the Question                                                                             | Categories/Codes of CUSL                                                                                                                                                                                                                                                                                                                                                                                           | Source                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|
| Q1- How do water cycle occur in your drawing? *<br><i>Possible sub-questions: **</i><br>- How clouds form?<br>- Could you please elaborate the process of _____?<br>- I see you included _____ in your drawing. Could you please explain your rationale? | To get in-depth information on their understanding on the working principles of water cycle     | <ul style="list-style-type: none"> <li>• General Characteristics of Water               <ul style="list-style-type: none"> <li>- Quantity of Water</li> <li>- Cyclic Nature</li> <li>- Water and Living Organisms</li> </ul> </li> <li>• Power Sources of Water Cycle</li> <li>• Components of Water System</li> <li>• Processes of Water System</li> <li>• Relationship between the Earth (Sub)Systems</li> </ul> | *Ben-Zvi Assaraf & Orion (2010)<br>** Pilot Study |
| Q2- Is there any starting/ending point in this cycle?<br><i>Possible sub-question:</i><br>- Could you explain what your rationale is to identify _____ as a starting/ending point?                                                                       | To get in-depth information on their understanding on cyclic nature of the water                | <ul style="list-style-type: none"> <li>• General Characteristics of Water               <ul style="list-style-type: none"> <li>- Cyclic Nature</li> </ul> </li> </ul>                                                                                                                                                                                                                                              | Ben-Zvi Assaraf & Orion (2010)                    |
| Q3- What can be the power sources for maintaining the water cycle?                                                                                                                                                                                       | To elaborate their understanding on power sources of the water cycle                            | <ul style="list-style-type: none"> <li>• General Characteristics of Water               <ul style="list-style-type: none"> <li>- Power Sources of the Water Cycle</li> </ul> </li> </ul>                                                                                                                                                                                                                           | Pilot Study                                       |
| Q4- Is there any system that interacts with the water cycle in your drawing?                                                                                                                                                                             | To explore how do participants explain possible interactions among the elements of water system | <ul style="list-style-type: none"> <li>• Relationship between the Earth (Sub)Systems</li> </ul>                                                                                                                                                                                                                                                                                                                    | Dutton (2015)                                     |

**4.3.2 Data Collection Procedure**

Data were collected during the fall semester of 2019-2020 academic year. Participants from the public schools were chosen based on the collaboration of school principals.

They provided necessary information for the selection of the participants based on given criteria. On the other hand, participants from private high schools were not chosen from the schools. They were selected purposefully among the available participants in researcher's network who met the criteria summarized above. All participants and their parents were informed about the purpose of the study. These details are given under the section of the "Ethical Considerations".

We worked with participants in two sessions. All interviews were face-to-face format and the researcher was the only interviewer to conduct the interviews. In the first session, each interviewee completed the first drawing task which is about drawing a diagram of natural water cycle. Then, the researcher asked them to explain their drawing and requested extra information related to their notion on water cycle. After completing this task, they filled out the conception test. The order of the first session was followed in all cases since conception test may give some hints about the first drawing task. Consecutively, second drawing task was started which is about depicting participants' local water system. At this point, some of them requested a definition for "what does a system mean?" After the introduction of the system, second drawing task was started. Unlike the first drawing, we were talking about their local system while they were drawing it. Throughout the questions, they added or modified some parts in their drawing. The first session took approximately 50 minutes including drawing tasks, conception test and interviews.



**Table 4-7***Interview Questions, Aims, and Categories of CUSL – Second Phase*

| <b>Translation of the Interview Questions</b>                                                                                                                                       | <b>Aim of the Question</b>                                                                                     | <b>Categories/Codes of CUSL</b>                                                                                                                                | <b>Source</b>                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Q1- What are the components of your local water system in your drawing?                                                                                                             | To get in-depth information whether participants identify major components in their local water system         | Components of LWS                                                                                                                                              | Pilot Study                                                          |
| Q2- Could you please explain where water comes from to your home?<br><i>Possible sub-question:</i><br>- Where does water come from to the storage tank/pipes/treatment plant/ dams? | To get in-depth information on their understanding about where water comes from to their home                  | Water Supply Network (WSN)<br>- Components<br>- Processes                                                                                                      | Covit et al., 2009<br>Pilot Study                                    |
| Q3- Could you please explain where wastewater go/discharge after domestic use?                                                                                                      | To elaborate whether participants explain where wastewater go/discharge after domestic use                     | Sewerage System<br>- Components<br>- Processes                                                                                                                 | Covit et al., 2009;<br>Ben-Zvi Assaraf & Orion (2010)<br>Pilot Study |
| Q4- Do you know which water resources are used in your hometown?                                                                                                                    | To explore whether the participants identify/exemplify water resources in their hometown                       | Local Water Resources (LWR)                                                                                                                                    | Pilot Study                                                          |
| Q5- Do you know the specific names of the water resources in your hometown?                                                                                                         | To identify whether the participants list water resources in their hometown                                    | Local Water Resources<br>- Names of LWR                                                                                                                        | Pilot Study                                                          |
| Q6- Is there any other system that interacts with your local water system in your drawing?                                                                                          | To get in-depth information whether participants explain interactions among the elements of local water system | Relationship among Local, National, and Global (Sub)systems                                                                                                    | Ben-Zvi Assaraf & Orion (2010)                                       |
| Q7- For what purposes do living organisms use water resources in your hometown?                                                                                                     | To get in-depth information whether participants explain interactions among the elements of local water system | <ul style="list-style-type: none"> <li>Relationship among Local, National, and Global (Sub)systems</li> <li>Local Water Resources- Functions of LWR</li> </ul> | Pilot Study                                                          |
| Q8- What do you think about Turkey's water resources potential?<br><i>Possible sub-question:</i><br>- Is Turkey one of the water-rich countries?                                    | To explore whether the participants are aware of that Turkey is not a water-rich country                       | National Water Resources-Current State of NWR                                                                                                                  | Pilot Study                                                          |

**Table 4-8**

*Interview Questions, Aims, and Categories of CRSL – Third Phase*

| Translation of the Interview Questions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Aim of the Question                                                                                                                                           | Categories of FSL / CRSL                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Q1- Where do you see the living organisms within the water system?</p> <p><i>Possible sub-questions:</i></p> <ul style="list-style-type: none"> <li>- What could be their possible effect(s) to the water system?</li> <li>- How could you classify these effect(s)? Positive or negative?</li> <li>- What could be the reason(s) for being neutral/ineffective in water system?</li> </ul>                                                                                                                                  | <p>To get in-depth information whether participants identify the role of living organisms in the water system</p>                                             | <p>FSL-Theme: Basics of Water System</p> <ul style="list-style-type: none"> <li>• General Characteristics of Water <ul style="list-style-type: none"> <li>- Water and Living Organisms</li> </ul> </li> <li>• Components of Water System</li> </ul>                                        |
| <p>Q2- Where do you see the human being(s) within the water system?</p> <p><i>Possible sub-questions:</i></p> <ul style="list-style-type: none"> <li>- What could be their possible effect(s) to the water system? <b><i>(If some of these keywords were stated, Q5, Q6, and Q7 will be asked: unconscious use, depletion of water resources)</i></b></li> <li>- How could you classify these effect(s)? Positive or negative?</li> <li>- What could be the reason(s) for being neutral/ineffective in water system?</li> </ul> | <p>To get in-depth information whether participants explain the effects of human beings in the water system</p>                                               | <p>CRSL-Theme 2: Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Beliefs on Water Use <ul style="list-style-type: none"> <li>- Collective use of water</li> <li>- Sources of beliefs</li> </ul> </li> </ul>                                                |
| <p>Q3- Where do you see yourself within the water system?</p> <p><i>Possible sub-questions:</i></p> <ul style="list-style-type: none"> <li>- What could be your possible effect(s) to the water system?</li> <li>- How could you classify these effect(s)? Positive or negative?</li> <li>- What could be the reason(s) for being neutral/ineffective in water system?</li> </ul>                                                                                                                                               | <p>To elaborate whether participants identify the role of his/her daily life activities in the water system</p>                                               | <p>CRSL-Theme 2: Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Beliefs on Water Use <ul style="list-style-type: none"> <li>- Self-use of water</li> <li>- Sources of beliefs</li> </ul> </li> <li>• Self-efficacy towards Efficient Water Use</li> </ul> |
| <p>Q4- What is your emotional response when you consider the effects of people/yourself on water system?</p> <p><i>Possible sub-questions:</i></p> <ul style="list-style-type: none"> <li>- What could be the reason(s) for your emotional responses?</li> </ul>                                                                                                                                                                                                                                                                | <p>To explore whether the participants identify any emotions associated with human effect on water system and analyze the reasoning behind those emotions</p> | <p>CRSL-Theme 2: Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Emotional response</li> </ul>                                                                                                                                                             |

Table 4.8 cont'. d

| Translation of the Interview Questions                                                                                                                                                                                                                                                                                                                                                                                        | Aim of the Question                                                                                                                                         | Categories of FSL / CRSL                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Q5- You mentioned that water had cyclic nature. So, how would the water cycle be affected when we use it unconsciously?                                                                                                                                                                                                                                                                                                       | To identify whether the participants predict the consequences of unsustainable human activities in water system                                             | CRSL- Theme 1: Advance Mechanisms in Water System <ul style="list-style-type: none"> <li>• Dynamic Nature of Water System</li> <li>• Causal Dynamics and Feedback Loops</li> <li>• Complexity of Water System <ul style="list-style-type: none"> <li>- Interruptions in the Water System</li> <li>- Layers of Complexities</li> </ul> </li> </ul> |
| Q6- How would unconsciously use of water affect the water system?                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                   |
| Q7- If the total amount of water is almost constant on Earth, why do we concern about the depletion of the water resources?                                                                                                                                                                                                                                                                                                   |                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                   |
| Q8- What could be the importance of maintaining the water system?<br><i>Possible sub-question:</i> <ul style="list-style-type: none"> <li>- Could you please explain your rationale?</li> <li>- How could the water system react when it encounters a problem?</li> </ul>                                                                                                                                                     | To explore whether the participants identify the importance of maintaining water system                                                                     | CRSL-Theme 2: Invisible Elements of Human System <ul style="list-style-type: none"> <li>• Motive Concern</li> </ul> FSL-Theme: Basics of Water System <ul style="list-style-type: none"> <li>• General Characteristics of Water <ul style="list-style-type: none"> <li>- Relational Responsiveness</li> <li>-</li> </ul> </li> </ul>              |
| Q9- What would you predict about the future scenario of your local water system?                                                                                                                                                                                                                                                                                                                                              | To explore whether the participants identify that water system and its subsystems are evolving                                                              | CRSL - Theme 1: Advance Mechanisms in Water System <ul style="list-style-type: none"> <li>• Evolution of Water System</li> </ul>                                                                                                                                                                                                                  |
| Q10- What would you predict about the future scenario of global water system?                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                   |
| Q11- Have you ever heard about the term "hidden use of water?"<br><i>Possible sub-question:</i> <ul style="list-style-type: none"> <li>- Could you please describe it?</li> <li>- Have you ever heard about the term "water footprint?"</li> <li>- Could you please exemplify the amount of water spending for a product(s)?</li> <li>- Which one of the products that you listed had the highest amount of water?</li> </ul> | To explore whether the participants <ul style="list-style-type: none"> <li>- identify hidden use of water</li> <li>- explain hidden use of water</li> </ul> | CRSL - Theme 1: Advance Mechanisms in Water System <ul style="list-style-type: none"> <li>• Complexity of Water System <ul style="list-style-type: none"> <li>- Interruptions in the Water System</li> <li>- Layers of Complexities</li> </ul> </li> </ul>                                                                                        |

Table 4.8 con.t

| Translation of the Interview Questions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Aim of the Question                                                                                                                                                                                                                                                                                                                                                                                                                                              | Categories of FSL / CRSL                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Q12- Please think about an average day of yours. In which activities do you spend water?</p> <p>Possible sub-question:</p> <ul style="list-style-type: none"> <li>- <b>If the participant was familiar with the term ‘hidden use’:</b> What about your hidden use of water in a day?</li> <li>- Let’s think about a product that you consume in a day, i.e a hamburger. Is it possible to spend water to produce a hamburger?</li> <li>- In which procedures of hamburger production could be spent water?</li> <li>- Who is/are responsible for this water consumption to produce a hamburger?</li> <li>- Could you please explain your rationale?</li> <li>-</li> </ul> | <p>To elaborate whether participants</p> <ul style="list-style-type: none"> <li>- identify the role of his/her daily life activities in the water system</li> <li>- explain hidden use of water</li> </ul>                                                                                                                                                                                                                                                       | <p>CRSL-Theme 2:<br/>Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Action Strategies for Efficient Water Use</li> </ul>                                                                                                                                                             |
| <p>Q13- Have you ever heard about the term “sustainable use of water”? <b>(If (s)he did not, ‘efficient use of water’ will be used instead of sustainable use of water for the next questions)</b></p> <p>Q14- Could you please share if you had any specific goal for sustainable/efficient use of water?</p> <p>Possible sub-question:</p> <ul style="list-style-type: none"> <li>- What is your rationale for using water sustainably/efficiently?</li> <li>- What are your specific strategies to achieve this goal?</li> <li>- Could you please share your rationale on not having a goal for using water sustainably/efficiently?</li> </ul>                           | <p>To get in-depth information whether the participants</p> <ul style="list-style-type: none"> <li>- set a goal relative to understanding sustainable water use</li> <li>- monitor how well he/she is using water efficiently based on his/her goal</li> <li>- identify and defend his/her accuracy about using water efficiently based on his/her goal</li> <li>- decide which human activities are contributing to sustainable water use</li> <li>-</li> </ul> | <p>CRSL-Theme 2:<br/>Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Beliefs on Water Use <ul style="list-style-type: none"> <li>- Self-use of Water</li> </ul> </li> <li>• Self-efficacy towards Efficient Water Use</li> <li>• Action Strategies for Efficient Water Use</li> </ul> |
| <p>Q15- Do you have any motivation to use water sustainably/efficiently?</p> <p>Possible sub-question:</p> <ul style="list-style-type: none"> <li>- What are the reasons that motivates you to use water sustainably?</li> <li>- Could you please explain your state of amotivation towards sustainable use of water?</li> </ul>                                                                                                                                                                                                                                                                                                                                             | <p>To elaborate whether participants identify his/her level of motivation towards sustainable water use</p>                                                                                                                                                                                                                                                                                                                                                      | <p>CRSL-Theme 2:<br/>Invisible Elements of Human System</p> <ul style="list-style-type: none"> <li>• Motivational Orientation for Efficient Water Use</li> </ul>                                                                                                                                                      |

**Table 4-9***Interview Questions of Reading Task, Aims, and Related Categories in CRSL*

| <b>Translation of the Interview Questions of Reading Task</b>                                                         | <b>Aim of the Question</b>                                                                                                                                                                                                                                                                      | <b>Types of System Literacy and Its Specific Categories</b>                                                                                                           |
|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Q1- What does the story tell us?                                                                                      | To check whether the story is clear to the participant                                                                                                                                                                                                                                          | -                                                                                                                                                                     |
| Q2- What are the components of the water system in the story?                                                         | To reveal whether participants identify the components of water system in the story                                                                                                                                                                                                             | FSL - Components of Water System                                                                                                                                      |
| Q3- What can be the sources of the failures in the water system?                                                      | To examine how the participants <ul style="list-style-type: none"> <li>- explain the interactions among three or more components</li> <li>- identify issues related to human effect on water system</li> </ul>                                                                                  | CRSL - Dynamic Nature of Water System<br>CRSL - Causal Dynamics and Feedback Loops                                                                                    |
| Q4- It was mentioned that seasons come earlier than before in that area. What could be the possible reason(s) for it? | <ul style="list-style-type: none"> <li>- predict the consequences of detrimental changes in water system</li> <li>- identify the climate change as a dynamic and complex issue within the water system</li> <li>- identify the importance of being a part of system as a human being</li> </ul> | CRSL - Complexity of Water System                                                                                                                                     |
| Q5- Which element(s) of the water system could possibly be affected by the seasonal anomaly?                          | To explore how the participants <ul style="list-style-type: none"> <li>- identify major components and processes in water system</li> <li>- explain interactions among the elements of water system</li> </ul>                                                                                  | FSL - Components of Water System<br>FSL – Processes in Water System<br>FSL – Relationship between the Earth (Sub)systems<br>CRSL - Causal Dynamics and Feedback Loops |
| Q6- Is it possible to revert the changes occurred because of the seasonal anomalies?                                  | To examine how the participants <ul style="list-style-type: none"> <li>- predict the consequences of detrimental changes in water system</li> <li>- state that water system and its subsystems are evolving</li> </ul>                                                                          | CRSL- Complexity of Water System<br>CRSL- Evolution of Water System                                                                                                   |
| Q7- If you were one of the local people, how would you feel about what happened?                                      | To examine how do participants express their emotions associated with human effect on water system                                                                                                                                                                                              | CRSL- Emotional Response                                                                                                                                              |

Before the second session, the researcher examined their conception test results as well as their drawings and responses to add some additional questions if it is necessary. In

the second session of the data collection, a semi-structured interview was conducted to depict their mental model on water system as well as their presumptions of their own water consumption behavior. After completing this part, a reading task about a real story - water system in a village- was given to the participants. Then, additional interview questions were asked related to this story. This second session lasted approximately 45 minutes.

Demographic information was taken from the participants during the different instances of the interviews. Both sessions were completed in the same conditions. Environmental conditions were checked before the sessions ensuring that light, air conditioning, and temperature are suitable for the data collection. All data collection processes were audiotaped by courtesy of the participants.

#### **4.4 Pilot Study**

Merriam and Tisdell (2016) emphasized that conducting a pilot study provides fruitful information for the researchers about their study. The authors also suggested that data collection, analysis, and lessons learned from the pilot studies should be reported. To test the data collection tools and their compatibility with the research questions, improving the codebook, and training myself as an interviewer, I conducted a pilot study at the end of the spring semester of 2017-2018 academic year. In this section, I reflected the construction phases of data collection tools, expert opinions and revisions, data collection of the pilot study, and lessons learned from the entire process.

##### *Preparation of the Data Collection Tools*

Data was collected during the pilot study through a paper-pencil test, a drawing task related to the water cycle, and an interview protocol. Before the construction of the data collection tools, three steps were followed to frame the context of the study. The first step was compiling a literature review chapter on scientific, environmental, and sustainability literacy, systems thinking, and specific studies related to water context in middle school level. This part enabled the researcher to (1) suggest an alternative

definition for systems literacy; (2) have a rudimentary idea about possible components of systems literacy; and (3) frame systems literacy in water context for the middle school graduates. Then, national science textbooks and its specific objectives (MoNE, 2018) related to water context were listed from the 3<sup>rd</sup> and 8<sup>th</sup> grade level. This step provided the researcher to see what an individual would be able to learn after completing the middle school degree. As a final step, all the questions within the data collection tools were refined by using the taxonomy of Marzano and Kendall (2008) since this taxonomy provides an in-depth information on individuals' declarative and procedural knowledge. Besides, this taxonomy also covers cognitive, metacognitive, and self-system which enabled to write a wide range of questions to understand the nature of the systems literacy in water context.

Conception test involved 20 questions in the form of multiple choice, matching, short answer, true-false items, and open-ended questions to explore participants' functional system literacy in water context. For the first 14 questions, an answer key for multiple-choice questions and rubrics for restricted-response essay questions were prepared. The nature of the other six questions could have more than one answer; therefore, no rubric was constructed for them. The content of the conception test was determined based on three steps summarized above. On the other hand, drawing task was about drawing a diagram of natural water cycle to provide another indicator for participants' FSL in water context. The semi-structure interview protocol included 17 questions to reveal participants' cultural and critical systems literacy.

The draft versions of data collection tools were sent to four reviewers to have expert opinions providing an indicator for content-related validity evidence. The researcher prepared an information sheet for the experts to explain the purposes of the study and a template to enable them to give their feedback in a standardized format. One assistant professor and one Ph.D. candidate who have experience on teaching and assisting the course of 'Measurement and Assessment in Education' were reviewed the questions in the data collection tools. They were also quite familiar with the framework of Marzano and Kendall (2008). They provided useful feedbacks on (1) compatibility

between the objective and the question, (2) selecting appropriate forms of test items, (3) suitability of the rubrics, and (4) alternatives in multiple-choice items (including distracters). Except from these experts, one professor and one associate professor reviewed the data collection tools in terms of its content and compatibility with the grade level. These reviewers' research interests were mainly ESD in science education and they had studies published in international and national journals. After the feedbacks, the data collection tools were refined.

#### *Data Collection Procedures in Pilot Study*

Data was collected during the pilot study by means of conception test, drawing task, and semi-structured interview. Conception test was administered to 358 eight-grade students in five schools from four different states in Ankara. Students from both rural and urban areas were included the study. The analysis of the conception test's responses served two purposes: (1) to provide an indicator for participants' FSL in water context and (2) to contribute to preparing a comprehensive codebook derived from open-ended questions. On the other hand, I interviewed six students (3 males, 3 females). I selected them from the same school in which I spent considerable amount of time in this school. I was one of the committee members that arrange extracurricular events related to science, mathematics, and English in that school on the weekends. The reason I chose this school is that I had prolonged engagement in there and school principals as well as teachers provided me necessary information for the selection of the potential participants. All the interviewees were voluntarily participated into the pilot study. As Merriam and Tisdell (2016) denoted, pilot interviews are very important for testing the interview questions and training the interviewers. Based on the responses of pilot interview, I revised some of the questions in terms of wording and added more questions for the main study. What is more, I also had a chance to talk about the conception test with the participants. They provided me useful feedbacks too for revising the conception test. Last but not least, I trained myself during the interviews in terms of (1) wait time, (2) being less anxious, and (3) less judgmental to



the responses of the participants. In short, pilot study sharpened my skills on item construction as well as being a better interviewer.

### *Lessons Learned from the Pilot Study*

After the analysis of the pilot study was completed, several changes and revisions were made based on the lessons that I learned during the process. Some additional items were appended, some were removed and some of them were revised to increase clarity. These changes were elaborated under the three elements of systems literacy.

When the findings of the pilot study within the context of *functional systems literacy* were assessed to design the next stage of the study, I detected some limitations. First, conception test, drawing, and interview protocol covered many aspects of water system based on the general principles of systems science. However, some alternative conceptions were appeared in students' responses and the aim of the pilot study was not compatible to explore them in detail. Therefore, from the findings of the pilot study, it was not clear whether the responses are derived from lack of knowledge, *in-situ* answers or misconceptions. To overcome this limitation, I modified conception test as four-tiered test which classified answers as (1) true, (2) false positive, (3) false negative, and (4) misconception. This conception test was elaborated based on the responses of 358 students as well as the literature (e.g. Schaefer, 2013). What is more, I increased the number of interview questions related to the functional to interpret participants' functional systems literacy in detail. I also modified the interview questions so that I would be able to detect whether they produced the answer *in-situ* or had resistant misconceptions.

When the findings of the pilot study in terms of *cultural systems literacy* were examined, I made some revisions for the next stage of the study. First, I removed some of the questions from the conception test since they were not as informative as it was intended. Then, I modified the context of drawing section for the next stage of the study. In the pilot version, students first drew water cycle and then explained their drawing. While these steps provide useful information about how participants perceive

both water cycle and water system as a whole, it did not give information about their cultural literacy. Hence, I decided to add a second drawing task related to their local water system that they live in. Consecutively, I also added interview questions related to their second drawing task to cover cultural systems literacy in-depth.

Based on the lessons learned from the pilot study, I decided to revise the parts that encompass the *critical systems literacy*. Some of the advance mechanisms of the water system were complicated to be interviewed explicitly. For example, the terms *dynamic nature*, *feedback loops*, and *complexity of the water system* were unfamiliar to the 8<sup>th</sup> graders. Alternatively, I decided to include a real story about a local water system so that we could be able to talk about these terms in an implicit manner. Before the pilot study, I had assumed that participants learn “sustainable development” in the 8<sup>th</sup> grade and we would be able to talk about sustainable water use. However, I experienced that they were not familiar the term that I imagined. Hence, I decided to use “efficient use of water” in the main study when I detected that the participants did not know about sustainable development as well as sustainable water use.

As I said earlier in this chapter, I decided to include participants from 9<sup>th</sup> grade students. The reason for choosing 9<sup>th</sup> graders was based on my observations during the pilot study. The last chapter related to water in the middle school science curriculum was at the end of the spring semester in 8<sup>th</sup> grade. As they would have national high school entrance exam at the end of the semester, they did not come to schools to study the exam in those days. Thus, participant selection from 8<sup>th</sup> graders would be limited and might not provide in-depth data for the main study. Accordingly, I chose 9<sup>th</sup> grade students at the fall semester to study since the first semester of the high school curricula does not contain the concept of water within the context of natural systems which might interact with participants’ systems literacy. Accordingly, I changed the grade level and time interval within the purpose of the study.

## **4.5 Data Analysis**

In this study, data analysis was conducted for both conceptual and empirical research parts. In the subsequent sections, data analysis in each part was summarized.

### **4.5.1 Data Analysis in Conceptual Research**

Patton (2002) basically described content analysis as analyzing written documents. In this dissertation, I used content analysis technique to summarize key points of the previous studies within the context of conceptual research. Accordingly, key previous studies on context-based literacies as well as systems thinking studies in educational context were analyzed through content analysis. Similarities and differences were portrayed. Possible integrations of the concepts and constructs to the context of systems literacy were determined. Summary of the studies, their similarities, differences, and possible integrations to the framework of systems literacy were given in the chapter 2, A Critical Literature Review on the Needs for Systems Literacy. On the other hand, proposed conceptual framework of systems literacy will be given under the chapter of findings.

### **4.5.2 Data Analysis in Empirical Research**

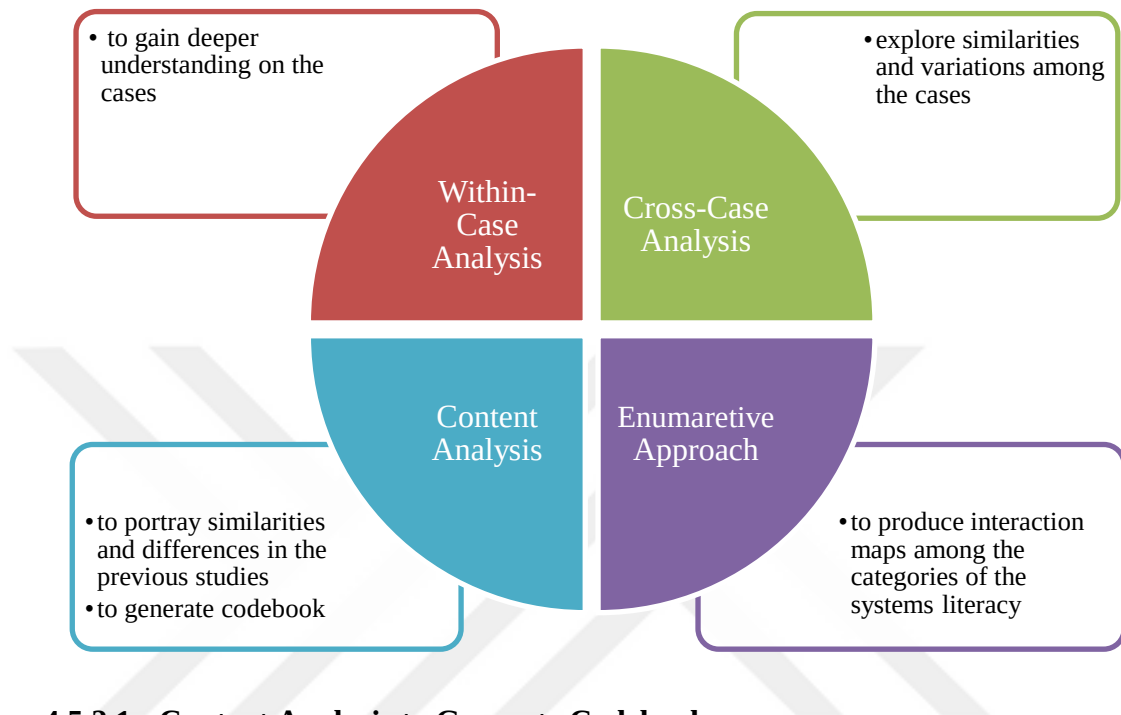
The conception test, drawing tasks and interviews were used as multiple data sources within the context of the study. Conception test's responses were coded as correct response, false positive, false negative, lack of knowledge, and alternative conception based on the different combinations of the responses. These combinations were provided in the answer key available in [Appendix A](#). On the other hand, qualitative data analysis was started with simultaneously with the data collection, data analysis proceeded iteratively throughout the research. For instance, I conducted the first session of the data collection. During the interview, I took some notes about my reflections. Before the second session of the data collection, I transcribed the first session's interview verbatim, read conception test, wrote my memos, and determine some additional questions if there are unclear points in participant's responses. During

the transcriptions and writing memos, rudimentary analysis took place along with the data collection (Merriam & Tisdell, 2016). Following the second session, I finished the transcriptions, I stored all data sources as a hardcopy and I also uploaded them on a cloud storage site. I repeated the same procedures for all participants for managing data efficiently. I transcribed all the interview by myself because I agree with Patton (2002) that transcription made by researcher enable his/her is beneficial for (1) bridging over data collection and data analysis, and (2) getting immersed in your own data. I used a free website for an efficient transcription where you can lower the speed of the interview to write the conversations simultaneously. Besides, I used pseudo names for the participants during the transcriptions for ensuring anonymous.

Multiple data analysis techniques were employed within the context of the study. As this was a multiple-case study, within-case and cross-case analyses were used (Patton, 2015; Merriam & Tisdell, 2016) to gain deeper understanding on the cases and explore similarities and variations among them. I used content analysis to generate codebook. Last, I used enumerative approach to produce interaction maps among the categories of the systems literacy. I explained them in detail in the subsequent sections. The data analysis was summarized in [Figure 4.1](#).

**Figure 4.1**

*Data Analysis Techniques Used in the Study*



#### **4.5.2.1 Content Analysis to Generate Codebook**

Another purpose of the content analysis is to seek understanding in voluminous qualitative data by forming possible themes and categories (Patton, 2015). Whereas content analysis is used in any qualitative study that includes inductive analysis (Merriam, 2009), it can be also integrated into specific qualitative methodologies such as in case studies (Patton, 2002). In this dissertation, I also used content analysis technique for constructing the codebook for systems literacy in water context since it enabled me to use both inductive and deductive coding during the data analysis.

Before the data collection, I determined *sensitizing concepts* which was considered as an inductive process (Blumer, 1969; Patton, 2015). In a broader sense, sensitizing concepts refers to the concepts based on “social science theory, the research literature, or evaluation issues identified at the beginning of a study” (Patton, 2002, p.456). Sensitizing concepts differs from the definitive concepts in a way that they provide

general frame (Patton, 2015) and “directions along which to look” (Blumer, 1969, p. 148). Accordingly, I determined three sensitizing concepts as “*functional systems literacy*”, “*cultural systems literacy*”, and “*critical systems literacy*” based on my preliminary literature review on systems science, general literary studies, and previous studies on systems thinking in educational context. Consecutively, I conducted the pilot study and its content analysis included both inductive and deductive coding. During the pilot study, I employed an inductive coding strategy to explore possible themes, categories, sub-categories, and codes within the context of these three sensitizing concepts. Simultaneously, I examined the literature review that I had done before to decide the accommodation of the categories. Hence, pilot study includes both inductive and deductive coding. In the main study, content analysis was realized as mostly deductive. Some minor adjustments were done to refine the codebook. All data in this dissertation were content analyzed to generate a comprehensive codebook (see Appendix C) for the systems literacy in water context. [Table 4-10](#) revealed the route of the content analysis. [Table 4-11](#) summarized elements of systems literacy and their correlated themes and categories.

**Table 4-10**

*Phases of Data Collection and Coding Strategies*

| <b>Phases of the Data Collection</b> | <b>Steps Followed during the Phases</b>                        | <b>Coding Strategies</b>                             |
|--------------------------------------|----------------------------------------------------------------|------------------------------------------------------|
| Exploratory Phase                    | Reviewing Previous Studies<br>Determining Sensitizing Concepts | Inductive<br>Deductive                               |
| Pilot Study Phase                    | Analysis of the Pilot Study<br>Revisiting the Literature       | Inductive<br>Deductive                               |
| Main Study Phase                     | Analysis of the Main Study                                     | Mostly Deductive +<br>Minor Inductive<br>Adjustments |

#### **4.5.2.2 Within-Case and Cross-Case Analysis**

Multiple case studies generally have two phases as *within-case* and *cross-case* analyses (Merriam & Tisdell, 2016; Patton, 2015). At first, each case is analyzed as if

they are the single comprehensive case. After the within-case analysis is finished, cross-case analysis is employed to explore the variations among the cases (Patton, 2015). Based on the order of the analyses suggested above, I firstly conducted within-case analysis. Consecutively, I used cross-case analysis to understand the variations within the responses of the participants.

#### **4.5.2.2.1 The Data Analysis of Functional Systems Literacy**

To portray their functional systems literacy, I inspired from a conventional scoring rubric. As the purpose of this study is not assess the achievement level of the participants, I traced fully correct statement(s), partially correct statement(s), and incorrect statement(s) in their responses and modified the conventional rubric and named it as '*Summary Table of Elements of Systems Literacy*'. In this summary table, I also integrated Taber's 'The Inclusive View' model (2008) and Marzano and Kendall's (2008) descriptions for different types of knowledge into the summary table for (1) differentiating the types of knowledge of the students as declarative and procedural knowledge to amplify their FSL; (2) delving into incorrect responses of the participants by using Taber's approach to discriminate them in terms of being stable or labile. This enabled the researcher to examine whether their incorrect responses were formed during the interview or based on stable and consistent alternative conceptions. In the early stages of within-case analysis, I traced responses by considering my sensitizing concepts. After the responses including indicators of FSL were classified, I used this summary table to organize, summarize, and portray their functional systems literacy in water context. [Table 4-12](#) revealed different responses having different level of correctness. Eren, for example, correctly revealed his both declarative and procedural knowledge related to the relational responsiveness of the water system. Ahmet, on the other hand, gave partially correct answer for wastewater treatment of his hometown. He correctly stated that wastewater goes to the creeks or seas akin to be treated in a treatment plant. However, he also talked about a second option which was discharging to another dam to retreat and reuse it. This response was *in-situ* and was not consistent throughout the interview. During the conversation, he

did not mention that option again and emphasized sea as a receiving environment. Hence, I labeled his response was both partially correct and inconsistently incorrect.

#### **1.2.1.1.1 Cultural Systems Literacy**

To portray their cultural systems literacy, I used the same summary table that I introduced in the previous section. I integrated Taber's 'The Inclusive View' model (2008) and Marzano and Kendall's (2008) descriptions for different types of knowledge into the summary table for several reasons. In the early stages of within-case analysis, I traced responses by considering my sensitizing concepts. After the responses including indicators of CUSL were classified, I used this summary table to organize, summarize, and portray their cultural systems literacy in water context. The only difference was that I added a column "Don't know". The reason is that CUSL permitted to detect if a participant had this specific knowledge or not. In the case of FSL, it was not possible to detect whether the participant know the answer or not due to the huge amount of knowledge for FSL in water context. Since tracing every piece of knowledge related to water and water system was not feasible and was beyond the scope of the study, I included "Don't know" only for CUSL summary table. This summary table was available in the findings chapter.



**Table 4-11***Themes and Categories of Systems Literacy in Water Context*

| <b>Elements of Systems Literacy</b> |         | <b>Themes</b>                      | <b>Categories</b>                                                                                                                                                                                               | <b>(Sub)categories</b>                              |              |
|-------------------------------------|---------|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------------|
| Functional Systems Literacy         |         | Basics of Water System             | General Characteristics of Water                                                                                                                                                                                |                                                     |              |
|                                     |         |                                    | Power Sources of Water Cycle<br>Components and Processes of Water Cycle<br>Relationship between the Earth Systems                                                                                               |                                                     |              |
| Cultural Literacy                   | Systems | Basics of Local Water System       | Components of Local Water System (LWS)                                                                                                                                                                          | Local Resources<br>Water Network<br>Sewerage System | Water Supply |
|                                     |         |                                    | National Water Resources<br>Relationship between LWS and (Sub)systems                                                                                                                                           |                                                     |              |
| Critical Literacy                   | Systems | Advance Mechanisms of Water System | Dynamic Nature of Water System<br>Causal Dynamics and Feedback Loops<br>Evolutionary Processes in the System<br>Complexity of Water System                                                                      |                                                     |              |
|                                     |         | Invisible Elements of Water System | Beliefs about Water Use<br>Self-efficacy towards Efficient Water Use<br>Motive Concern<br>Action Strategies for Efficient Water Use<br>Emotional Response<br>Motivational Orientation for Sustainable Water Use |                                                     |              |

#### 4.5.2.2.2 Critical Systems Literacy

Critical literacy involves necessary skills to grasp a context in terms of cultural, social and political aspects and develop a personal and social response to that context (Stables, 1998). Moreover, Stables exemplified that individuals who have critical environmental literacy are able to explore the factors influencing an environmental change and suggest possible actions that may revert that environmental change.

Within the context of the study, I aimed to explore graduate middle school students' level of (1) grasping water system's dynamic nature on multiple time scales; (2) being aware of potential effects of different time scales; (3) explaining different types and levels of complexity in water cycle/system which can be the basis for disruption or failure; (4) describing evolutionary processes of water system when it interacts with human systems; (5) explaining feedback loops which are for regulating subsystems to provide maintenance; (6) inferring that water systems includes models of other systems; (7) predict that different mental models of humans may interfere with the water system; and (8) appreciating that water system on Earth can be understood and improved. Besides, individuals who comprehend these principles of systems could be able to (9) decide to involve actions to provide maintenance of any system; and (10) set goals themselves to change their behavior.

To explore their critical systems literacy, I provided thick description of my analysis to portray participants' CRSL. In the early stages of within-case analysis, I traced responses by considering my sensitizing concepts. After the responses including indicators of CRSL were classified, I analyzed them to explain participant's profile in-depth. The reason for not constructing a summary table is that the characteristics of CRSL was not suitable for scoring but it needs to be reported in detail. However, I employed several theoretical frameworks for analyzing CRSL since it included several constructs whose descriptions and variations are diverged within their own literature. [Table 4-13](#) summarized these theoretical frameworks.

**Table 4-12***An Example of Analysis for FSL*

| Sample Excerpt from Interview Questions                                                                                                                                                                                                                                                                                                                                                                                        | Categories of SL                                     | Status of Response                                             | Types of Knowledge       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|----------------------------------------------------------------|--------------------------|
| <i>Eren:</i> It reacts... Of course, this reaction is not like human-brain-reaction but rather action-reaction. If we act, it reacts. For example, as I said earlier, due to our action (referring man-made greenhouse effect), its reaction will be the increase in the rate of evaporation. Then it condenses more. This is a reaction because of our action. After a while, drought or flood may emerge due to our actions. | Relational Responsive ness                           | Fully Correct Statement                                        | Declarative + Procedural |
| <i>Ahmet:</i> [Domestic wastewater] goes to the creeks or seas from the basins. Or it could be discharged to another dam to retreat and reuse it again. ( <i>he thought a minute</i> ) ... I think they are treated in a treatment plant and then discharged to the sea. So, there could be two options.                                                                                                                       | Components of LWS-Sewerage system                    | Partially Correct Statement + Incorrect-inconsistent Statement | Declarative              |
| <i>Cansu:</i> As there is no recycling for some water which penetrates the soil and leaks to the groundwater, the total amount of water decreases. For example, some of our wastewater in our village goes into the soil and it would not be usable anymore. I think this situation affects all the world since it leads to a decrease in the total amount of water on Earth.                                                  | General Characteristics of Water - Quantity of Water | Incorrect-consistent Statement (alternative conception)        | Procedural               |

**Table 4-13***Themes/Categories of CRSL and Their Theoretical Frameworks*

| <b>Themes / Categories</b>               | <b>Theoretical Framework</b> |
|------------------------------------------|------------------------------|
| Advance Mechanisms of Water System       | Mobus & Kalton (2015)        |
| - Dynamic Nature of Water System         |                              |
| - Causal Dynamics and Feedback Loops     |                              |
| - Evolutionary Processes in Water System |                              |
| - Complexity of the Water System         |                              |
| Beliefs on Water Use                     | Fishbein & Ajzen (1977)      |
| Self-Efficacy Beliefs                    | Bandura (1997)               |
| Motive Concern                           | Stern & Dietz (1994)         |
| Motivational Orientation                 | Ryan & Deci (2017)           |

**4.5.2.2.3 Enumerative Approach for Mapping the Interactions among the Categories**

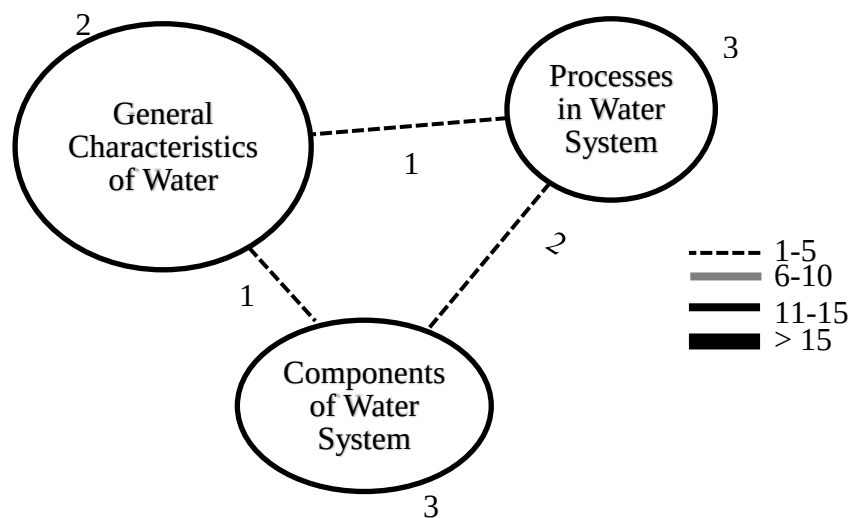
Enumerative approach was introduced by LeCompte and Preissle (1993) as a data analysis technique. This analysis technique was employed in qualitative research to reveal frequencies related to the presence of the categories. Different representations were available in qualitative studies (e.g. Park & Chen, 2012; Cullicott & Chen, 2018). Producing an interaction map among the categories was employed by Park and Chen (2012) in the Pedagogical Content Knowledge context. This structure of interaction map – they called it PCK map - was used to portray the integration of the categories of specific literacy type as well as among FSL, CUSL, and CRSL. When the responses were analyzed during the within-case analysis, connections among the categories were counted “with the assumption that there must be at least one connection between any two of the identified components in a special way.” (Park & Chen, 2012, p.929). In other words, if two categories were determined as related to each other, then one

connection was counted. If more than two categories were related to each other, then any two of the categories was counted as a connection. Each connection was counted as “1” even though the strength of each pair may not be equal.

Assume that there is a dual interaction between process in water system and components of water system. Moreover, there is also a triple interaction among general characteristics of water, processes in water system, and components of water system. The sample interaction map was given in Figure 4.2.

To sum up, multiple data analysis techniques were used for the data analysis of this dissertation. Qualitative content analysis was used for generating a comprehensive codebook for systems literacy in water context. Within-case and cross-case analysis were employed for gaining a deeper understanding for each case as well as the variations amongst the cases. To reveal the interactions among (1) the categories within the specific systems literacy and (2) the types of three literacy forms, interaction maps were produced. Each data analysis technique complemented each other and provided a holistic profile for systems literacy in water context.

**Figure 4.2**



*Sample Interaction Map of Categories in FSL*

## 4.6 Trustworthiness of the Study

### 4.6.1 Credibility

Credibility can be considered as a substitute of internal validity in quantitative research design. In a general sense, it addresses how the findings of study is congruent with the reality (Merriam & Tisdell, 2016). As the notion of reality changes in philosophical worldviews, credibility can be expressed as “are the findings *credible*, given the data presented?” (Merriam & Tisdell, 2016, p.242). Accordingly, to enhance the credibility of the study, data triangulation, adequate engagement in data collection, peer examination, and researcher’s reflexivity were addressed.

Patton (2015) highlighted that, “triangulation, in whatever form, increases credibility and quality by countering the concern (or accusation) that a study’s findings are simply an artifact of a single method, a single source, or a single investigator’s blinders” (p. 674). Among the different types of triangulation, multiple methods of data collection were used. Semi-structured interviews, drawing tasks, and conception test were three methods of data collection. During the data collection and analyses, the researcher appreciated its powerfulness for enhancing credibility. As an example, Eren mentioned 18 out of 31 components in the water system. These 18 components were acquired in different methods of data collection as one in conception test, five in his drawings, and 12 in the interview responses. In the case of single data collection method, the researcher would not be able to converge this finding.

*Adequate engagement in data collection* is another strategy to decide the number of interviewees or time interval for observation (Merriam & Tisdell, 2016). Although there is no definitive answer for this strategy, *saturation of data* and *discrepant case analysis* are suggested (Patton, 2015; Merriam & Tisdell, 2016). In this study, the researcher continued collecting data until she felt that it was saturated. This happened when no new information was collected. Accordingly, four participants rendered diverse and fruitful information about the systems literacy in water context.

*Peer examination* is a strategy that an external person “scan some of the raw data and assess whether the findings are plausible, based on the data. (Merriam & Tisdell, 2016). Peer examination strategy was employed both in the pilot and the main study. The advisor and co-advisor of the researcher reviewed and shared their experiences and provide fruitful feedbacks during the pilot and the main study. Their revisions and comments broadened the researcher’s horizon throughout the research. They also provide feedbacks during instrumentation and data analysis (preparing codebook, content analysis, and mapping the interactions) stages. In addition, the draft versions of data collection tools were sent to two other reviewers to have expert opinions. Additionally, two experts were invited to analyze some portion of the pilot and the main study data. One expert was a Ph.D. candidate in elementary science education and had a master thesis on multiple-case study. This expert provided a content analysis for 25% of the pilot study data, specifically for open-ended questions in the conception test. He also gave feedback for the draft version of the codebook. For the main study, another expert who had a master thesis on systems thinking analyzed full data of one of the participants. He used deductive coding by using the codebook that the researcher constructed. What is more, he used summary tables for location participant’s FSL and CUSL. The expert suggested also some minor changes for the codebook and the summary tables in addition to data analysis.

*Reflexivity* refers to (Merriam & Tisdell, 2016, p.249) “Investigators need to explain their biases, dispositions, and assumptions regarding the research to be undertaken.” In other words, reflexivity is about interactions between the researcher’s research process (Probst & Berenson, 2014). It also enables audience to grasp how the researcher make inference from the data (Merriam & Tisdell, 2016). Similarly, Patton (2005) highlighted that credibility of a researcher is based on the experience that (s)he has. Accordingly, I tried to express my qualitative research experiences as well as my area of expertise that might be interacted with my research process. In terms of qualitative research background, I have not enrolled a qualitative class. However, I have read some inspiring textbooks written by different authors such as Merriam and

Tisdell (2016); Patton (2015); Yıldırım and Şimşek (2006); and Creswell (2007) during my Ph.D. journey. I have also read some of the chapters, specifically sampling and data collection, in Yin (2018) and Stake (2015). These readings enabled me to discover my dispositions towards qualitative research and accordingly, I chose Merriam's and Patton's ways of conducting qualitative research which are compatible my worldview. Besides, I conducted some qualitative studies with my colleagues during Ph.D. and we had opportunities to present them in international and national conferences. Sharing our studies with the other peers and exchanging ideas strengthened my qualitative research background. Last but not least, conducting a pilot study help me sharpen my skills on conducting effective interviews and qualitative data analysis. During the main study, I systematically wrote my thoughts and feelings towards the students as well as the interview process. This enabled me to monitor my subjectivity during the study.

In terms of the content of the study, I have several experiences, too. More than seven years, I have been a research assistant at the department of mathematics and science education. I am working on specifically education for sustainable development in elementary science education context. Hence, courses that I assisted and observations that I made at the middle schools enable me to engage in the concepts of water in science education as well as in education for sustainable development. Hence, I am quite familiar about (1) how middle school students are taught the concepts of water; (2) what types of possible extracurricular activities that students participates in related to the water context; (3) the background knowledge of the pre-service teachers and how they reflected them in the classroom; (4) what type of misconceptions/ alternative conceptions students and pre-service teacher had related to the processes in the water cycle; (5) the level of systems thinking skills of pre-service science teachers. What is more, I have been invited as a guest speaker to some public and private schools to give seminars on the water system, climate change and water footprint. Being a guest speaker provided me some opportunities to examine students' responses and comments related to the water system. These experiences guided me to prepare



interview questions as well as monitoring the semi-structured interviews. For example, I experienced that most of the middle school students that I interacted with have not never the term “hidden use of water”. However, I also had experiences that they had ability to infer the water consumption for a product. Accordingly, I prepared some follow-up questions to explore their levels of inference for the water consumption of a product. I specifically selected a product that they consume, a hamburger. In the case of lacking these experiences, I would not ask them these follow-up questions and the progress of the interviews might be different than its present state.

Most of the participants during the pilot study and the main study stated that they astonished at some of the interview questions. For instance, when I asked to them where their tap water coming from, they stated that they had never thought about these questions before. All of them were very curious during the study for the correct responses. I informed them that I would answer their questions at the end of the data collection. Even some students contacted me later to ask some further questions on the water system.

#### **4.6.2 Dependability**

Dependability seeks to answers for “whether the results are consistent with the data collected” (Merriam & Tisdell, 2016, p.251). Strategies for enhancing dependability were outlined by Merriam and Tisdell as triangulation, peer review, reflexivity, and the audit trail. The first three strategies were given in detail in the previous section. Audit trail includes “how data were collected, how categories were derived, and how decisions were made throughout the inquiry.” (Merriam & Tisdell, 2016, p.251). In this study, memos were recorded throughout the research process. The researcher included her reflections, questions, as well as derivation process of the themes and categories. She reminded herself how her decisions are shaped during the research.

During the time of COVID-19 Pandemic, peer examination was a limited strategy due to lack of face-to-face interaction to compromise to resolving disagreements. Thus,

even though the researcher followed Merriam's and Patton's approach for qualitative study most of the time, she added intra-coding as an exclusive strategy for enhancing dependability. This strategy was suggested by Miles and Huberman (1984) to enhance consistency of the researcher in time. Accordingly, the researcher analyzed the entire data of the main study twice. The time interval between the analyses was approximately five weeks. She employed the formula of inter-rater reliability and calculated the reliability coefficient as 0.91. Adhering to emerging disagreements with the first coding, she reached full agreement.

#### **4.6.3 Transferability**

Transferability includes how the findings of a qualitative research can be generalized to different settings (Merriam, 2009). Transferability was addressed by including *rich, thick description* and *maximum variation* as recommended by Merriam and Tisdell (2016) and Patton (2015). The researcher provided a detailed description of the participants' profile, data collection and analysis procedure and the findings as well by using multiple sources of data. Maximum variation, on the other hand, were defined as "to give careful attention to selecting the study sample" (Merriam & Tisdell, 2016, p. 257). Accordingly, the researcher selected the participants of the study based on some criteria given in "Selection of the Participants". In this way, she tried to include different cases that enabled her to explore the variations among the participants.

#### **4.7 Ethical Considerations**

Before starting the data collection, ethical issues outlined by Fraenkel, Wallen and Hyun (2012) were carefully considered. Data collection tools and data collection procedures was planned based on the ethical considerations. After data collection tools were finalized, they are sent to Research Center for Applied Ethics of Middle East Technical University to get approval. This approval process, then, was replicated for Ankara Provincial Directorate for National Ministry of Education. The approval forms were available in [Appendix D](#). The researcher contacted two public high schools after

these approval processes were concluded. School principals suggested students as potential participants that meet the selection criteria of this study. The researcher explained student the purpose of the study briefly and informed that they could participate in study if they were volunteers and their parents approved the participation. Participants from the private schools, on the other hand, were selected purposefully among the available participants in researcher's network since they meet the criteria summarized above. The participants and parents were also informed about the purpose of the study both in oral and written forms. Parents of all four participants signed parent permission form before the data collection. The sample parent permission form was available in Appendix E. Before the data collection, the researcher reminded the participants that they are allowed to withdraw any question that they did not want to answer or withdraw the study completely at any time. During the data collection, she was also careful about her attitude congruent with the ethical considerations. After the data collection completed, the personal information of the participants as well as the audio-recordings and transcripts were protected. Researcher used pseudo names for each participant for being anonymous.

## CHAPTER 5

### FINDINGS

*“Let there be work, bread, **water** and salt for all.”*

*Nelson Mandela (1994)*

This chapter is devoted to the philosophical conceptualization and an introduction to alternative conceptual framework of systems literacy in water system context. First, conceptual model of systems literacy was described and presented. Second, hypothetical systems literacy in water context was given. Third, the findings of empirical research were reported and the researcher’s alternative framework of systems literacy in water system context was finalized.

#### 5.1 What is Systems Literacy?

The purpose of this section is to summarize the conceptual findings of the study. The conceptual definition of the systems literacy was given in this part. Then, three elements of systems literacy were elaborated.

As an output of the conceptual research and analyzing them in a critical manner, systems literacy is defined by the researcher of this study as following:

Systems literacy is about being able to perceive systems that we interacted with and the courses of our actions that interfere with those systems. This perception encompasses not only the level of knowledge about the general principles of systems but also includes cultural components as well as a set of other psychological constructs that might have a role in understanding and engaging those systems. A typical systems literate individual is expected to be sufficiently critically systems literate that relies on both adequate level of functional and cultural systems literacy. What is more, systems literature individuals are the ones who could be able to be aware of the fact that human systems have a potential to influence both the system mechanisms and individual and collective human behavior in a system.

Compatible with the general literary frameworks, the definition done by Stables (1998) was used as a guide to elaborate the notion of systems literacy. By using this theoretical framework, systems literacy is composed of three elements as *functional systems literacy*, *cultural systems literacy*, and *critical systems literacy*. In the subsequent sections, these elements were introduced.

#### **5.1.1 Functional Systems Literacy**

In general, functional literacy corresponds to literal comprehension (William & Sniper, 1990) on a superficial level in a given context. While describing *functional systems literacy*, the researcher of this study merged the *PR1*, *PR2*, *PR3*, *P7*, and *PR11* from the general principles of systems (Mobus & Kalton, 2015) which were described in the previous section; functional literacy in general as well as functional environmental literacy (William & Sniper, 1990; Stables, 1998); and some of the basic systems thinking skills (Ben-Zvi Assaraf & Orion, 2005). Correspondingly, the researcher described individuals who are *functionally systems literate* as following: individuals are expected to be able to not only describe a system either in an implicit or explicit manner, but also identify system(s) that they live in. They also could be able to infer that systems are composed of other subsystems and explain that there are components, processes, and relations which are organized and functioned by the system. In addition, individuals who are functionally systems literature could be able to show networks within a system by drawing the interactions or unfold the relations by examining a visual representation of a system. Moreover, systems-literate individuals are also able to state that systems are continually evolving and encoding knowledge and receiving and sending information. By the time they are doing these, it is not expected individuals to draw any conclusion for maintaining a system or systems evolution processes.

### 5.1.2 Cultural Systems Literacy

Stables (1998) and Williams and Snipper (1990) denoted that cultural literacy demands an ability to comprehend the importance of cultural icons on society. These icons can be either living or non-living things or both at the same time. In this element of literacy, cultural literacy permits individuals to appreciate the importance of these icons in human culture and the reasons for their importance. While constructing *cultural systems literacy*, the researcher of this study merged the *PR1*, *PR2*, *PR3*, and *PR11* from general principles of systems science (Mobus & Kalton, 2015), but this time, in local context; cultural literacy in general as well as cultural environmental literacy (William & Sniper, 1990; Stables, 1998); and some systems thinking skills (Ben-Zvi Assaraf & Orion, 2005). Within the context of this study, the researcher described individuals who are *culturally systems literate* as following: individuals not only describe a system either in an implicit or explicit manner in a local context, but also identify the importance of system(s) that they live in it. Moreover, individuals who are culturally systems literate are expected to be able to infer that local systems are also composed of other subsystems and explain that there are components, processes, and relations which are organized and functioned by the system. In addition, individuals who are culturally systems literate could be able to show networks within a local system by drawing / explaining the interactions or unfold the relations by examining a visual representation of a local system. While they are doing these, it is not expected them to draw any conclusion for maintaining a local system or systems evolution processes.

### 5.1.3 Critical Systems Literacy

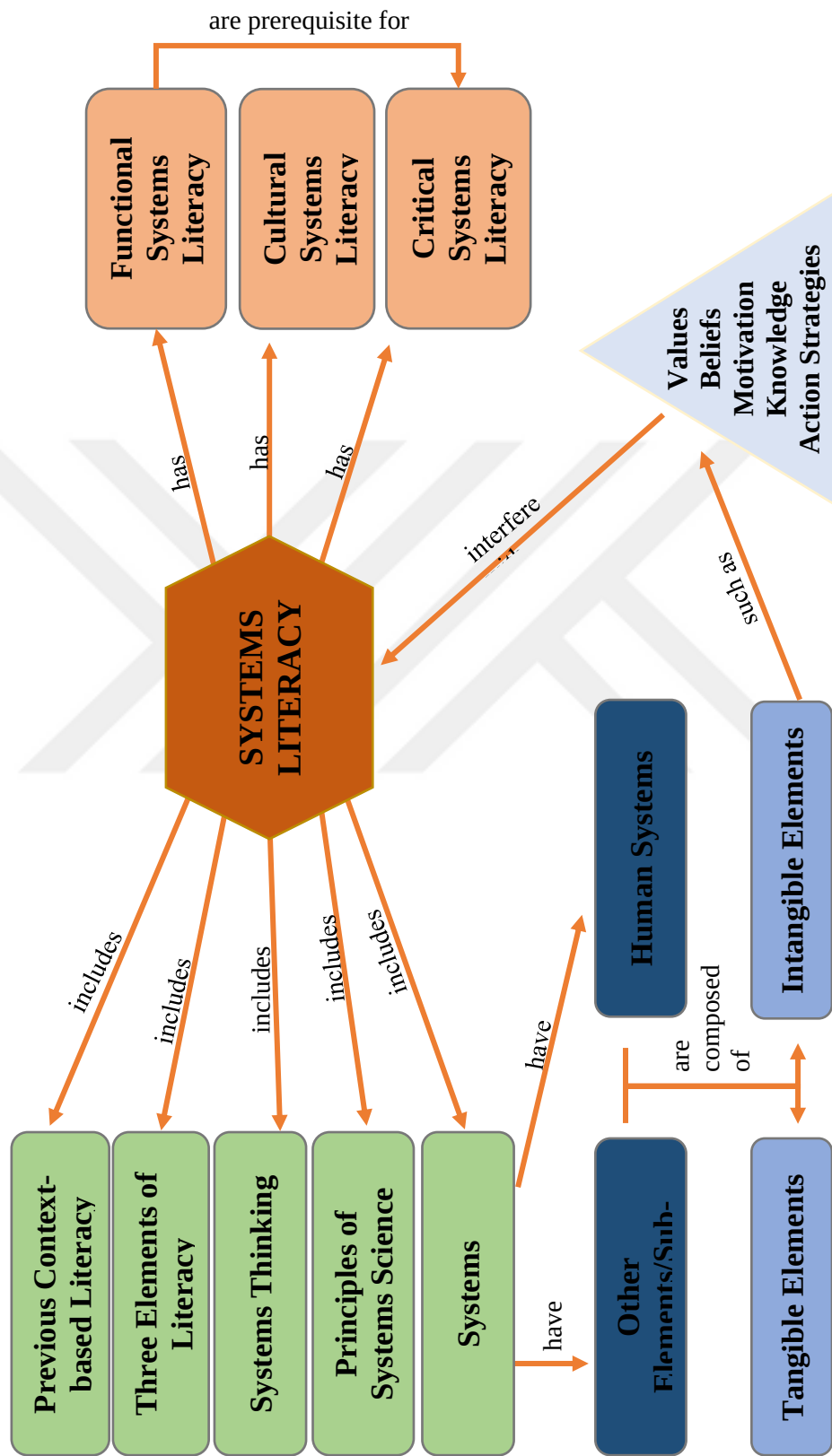
Critical literacy involves “*the ability to 'get behind' the text to interpret it in terms of its ideological underpinnings...*” (Stables, 1998, p.157). It includes necessary skills to grasp a context in terms of cultural, social and political aspects and develop a personal and social response to that context. Moreover, Stables exemplified that individuals who have critical environmental literacy are able to explore the factors influencing an

environmental change and suggest possible actions that may revert that environmental change. While describing *critical systems literacy*, the researcher of this study merged the remainder of nine principles of systems (Mobus & Kalton, 2015) which were given in the previous section; critical literacy in general as well as critical environmental literacy (William & Sniper, 1990; Stables, 1998); and systems thinking skills (Ben-Zvi Assaraf & Orion, 2005; Sterling, 2005). Moreover, invisible elements of human system mentioned by Henning and Chen (2012) were also integrated into the critical systems literacy.

Stables (1998) argued that critical literacy demands both functional and cultural literacy. In a similar manner, the researcher described individuals who are *critically systems literate* as following: critically systems literate students are expected to have adequate level of functional and cultural systems literacy. In addition to this prerequisite, an adequate level of critical systems literacy enables individuals to (1) grasp systems in its dynamic nature on multiple time scale; (2) be aware of potential effects of different time scales on system dynamics; (3) explain different types and levels of complexity in a system which can be the basis for disruption or failure within a system; (4) describe evolutionary processes of systems as going upward, stay steady, or going downward; (5) draw or explain feedback loops which are for regulating subsystems to provide maintenance; (6) infer that systems includes models of other systems; (7) appreciate that any complex, adaptive system (e.g. human systems) may include model of itself (e.g. mental model) and predict that different mental models of humans may interfere with the interaction between man and nature; and (8) appreciate that systems can be understood and improved. What is more, invisible elements of human system have some characteristics that potentially interferes with the water system. Consequently, the elements of beliefs, action strategies, self-efficacy beliefs, motive concerns, emotional response, and motivational orientation for maintaining a system were also potential constructs to indicate individuals' critical systems literacy. In short, conceptual model for systems literacy based on the conceptual research was visualized by the researcher as given in Figure 5.1.

**Figure 5.1**

*Conceptual Model of System Literacy*





## **What Is the Alternative Framework of Systems Literacy in Water System Context for Students Completing Middle School Degree?**

The purpose of this section is to describe systems literacy in the water system context. Compatible with the purposes of the study, water system and human system were defined operationally as complex adaptive systems within the context of principles of science. Then, conceptual definition of the systems literacy in water system context and its three elements of systems literacy were elaborated based on the conceptual research and pilot study findings.

### **5.2.1 Water System as A Complex Adaptive System**

Water system is assumed as one of the complex adaptive systems (CAS) by the researcher based on the conceptual research. Water system has several characteristics compatible with like other CAS as “...*class of networks that are not just dynamic but show organizing behaviors that are a result of growth and/or change in composition and/or density.*” (Mobus & Kalton, 2015, p.147). Natural water cycle, living organisms as users of water, and human use of water are some of the examples for class of networks that are dynamic in their nature. Moreover, these networks could be able to respond any change in any components, processes, or interactions occurs within CAS. As an example, rate of evaporation changes due to increase in global temperature (a.k.a. global warming). Alternatively, water pollution occurs due to discharging of city sewage or industrial waste (WWF, 2019). What is more, human activities show some organizing behaviors to reverse the process such as stop discharging or constructing wastewater treatment systems to prevent further pollution. These are all can be accounted for showing the dynamic nature of water system. Secondly, as Mobus and Kalton emphasized, CAS are able to show some lifelike actions as if they are alive. In other words, they produced some actions or responses to changes in their surroundings just like a living organism. Self-directedness, self-correction, self-preservation, and intelligence are some of the features of CAS lifelike activities

(Camazine et al., 2001). In the same manner, water system on Earth tends to show such lifelike qualities. Third, Mobus and Kalton stated that (p.243)

Living systems are the most elegant examples of complex adaptive systems, with a nested hierarchy of levels of adaptive strategies at scales from individual organisms to species to ecosystems or societies and their manifold institutions. The Earth as a whole, taking in the whole web of life in a constant interwoven flow of energy, material, and information, is probably the ultimate unit in this CAS hierarchy of life.”

As mentioned above, water system is a CAS containing nested levels from specific organisms to multiple organizations. Due to these reasons summarized above, water system on Earth can be considered as a CAS. In the next parts, water system is identified by means of general principles.

#### *Principle 1: Systemness*

According to this principle, the universe is a system having many (sub)systems which are also be considered as systems in different settings (Mobus & Kalton, 2015). In other words, each system can be a constituent of another larger system. In a similar vein, water system has many subsystems such as natural water cycle, different habitats that are dependent of water, water supply network in cities, human beings as well as societies. They could be identified both systems and subsystems at the same time within the water system. Other examples for the principle of systemness can be given as following: River is a system having physical, chemical, and biological processes. A dam in that river, on the other hand, can be considered as another system having many components and processes to store water or produce electricity. Water treatment systems are artificial systems constructed by humans to acquire drinking water and distribute it to the cities. In the same manner, the wastewater produced from the cities are also treated in the wastewater treatment systems and then discharged into the same river that we exemplified. Besides, any person, family, district, and province are can be considered as systems that use the water from the river. At the larger scale, catchment areas, and countries are some other systems that use water from different water resources. Water system described in this study is a system that encompasses

these nested subsystems. These subsystems can be also considered as systems in different frame of reference.

*Principle 2: Systems Are Processes Organized in Structural and Functional Hierarchies*

Systems could be regarded as processes demonstrating dynamic interactions among the constituents of the system (Mobus & Kalton, 2015). Hierarchies in this principle refers to the ways that systems inherently consolidate their structures and functions within their working mechanisms. Within the context of this study, water system has also many components and interactions organized in structural and functional hierarchies. For example, we can start from the very basic subsystem, natural water cycle, within the water system. Natural water cycle has many components and processes such as oceans, glaciers, freshwater, evaporation, infiltration, precipitation and these components and processes are organized in different structures and functions within the working mechanism of the natural water cycle. At the next level of process, there are living things who use water for survival purposes. All living things have processes in their body to use water for different purposes. Among the living things, human use of water forms another interwoven system or process beginning from individuals to societies. Every nation uses the water in their own way; some use water resources more than they need, whereas some people have to struggle with reaching out drinking water every day.

*Principle 3: Systems Are Networks of Relations Among Components and Can Be Represented Abstractly as Such Networks of Relations*

In this principle, it is highlighted that components are connected by different linkages and each linkage may have different directions and functions (Mobus & Kalton, 2015). This principle is correlated with *PR9* and *PR11* which we will discuss later. Different visual tools serve to understand system mechanisms to explore the nature of the relationships and flows within a system. We can visualize the system mechanisms in two ways. We can model the systems, or we can produce different formulas or

notations to understand them in depth. For example, the diagram of water cycle in the science textbook enables students to understand the networks of relations among the components of water cycle as well as the movement of water on Earth. What is more, we can visualize the cause-effect as directions and strength of influence and recognize multiple cause and/or effects as well. At this point, water system is an incredibly complex network. Water pollution and human use of water are some of the phenomena that have multiple effects on the water system. While we are able to predict some of these effects, there are still unexpected consequences. Yet, we are still able to model these networks of relations abstractly.

*Principle 4: Systems Are Dynamic Over Multiple Spatial and Time Scales*

According to Mobus and Kalton (2015), processes in a system depend on its spatial and time scales. For instance, while some molecular reactions take micro- and milliseconds, geological events may last over centuries. Here, it is essential to note that these dynamical mismatches may have undesirable effects on the sustainability of the systems. In the case of the water system, while evaporation happens at any temperature in minutes, drinking water takes many years to form again in/on the land. Moreover, unconscious use of water and slow pace of increasing awareness of people about the efficient water use exacerbates availability of drinking water. These dynamical mismatches are one of the reasons for water scarcity at some places on Earth.

*Principle 5: Systems Exhibit Various Kinds and Levels of Complexity*

Complexity is one of the properties in Systemness. As to Mobus and Kalton (2015) emphasized, systems have different types and / or layers of complexity. On the other hand, they also denoted that complexity and nonlinearity can be reasons for interruptions and failures in systems. Let us explore one of the issues in the water system: water scarcity. The problem of water scarcity is not just a problem related to water shortage, but it is also survival, economic, social, educational, governmental, and health problem. All of these layers show different levels of complexities in them.

In the same manner, Mobus and Kalton reported that societies can be very complex when they attempt to determine and solve a local problem. Unsustainable use of water can be an example of such type of complexity since even though we recognize the probable effects on unsustainable water use in a long run, we are still too slow to change our habits to use water sustainably. Our complexity can be one of the sources of disruption in the water system.

#### *Principle 6: Systems Evolve*

As Mobus and Kalton (2015) emphasized, evolution of systems can be classified as (1) evolving toward higher organization, (2) sustaining its steady-state, or (3) decaying. The perception of evolution, on the other hand, depends on the observer's frame of references. For example, from the appearance of very first human, we have been increasing in numbers and improve new technologies. As a result, we can claim that humanity evolved toward higher organization as time passes. However, these improvements bring out unpredicted problems and issues on the agenda which may, in turn, result in decaying in our system. Therefore, we may infer that the processes that make us evolve toward higher organization may decay our system in the future. Within the context of the water system, decrease in availability of water, water scarcity or depletion of water resources can be some of the example of decaying. On the other hand, sustainable water use for the sake of future generations can be an example of maintaining our water system at steady state. Using bio-manipulation in a polluted lake to restore its habitat can be an example of an evolution towards higher organization in that water system.

#### *Principle 7: Systems Encode Knowledge and Receive and Send Information*

Before explaining this principle, it can be useful to highlight that “*mental way of possessing knowledge and processing information*” (p.27) is different from the physical way since living organisms encode knowledge and receive and send information in a more complicated and nested manner than the non-living systems. In non-living systems, knowing “how to act” does not need to have a brain, but necessary

*structure*. For example, free fall in physics does not require brain, but all the object in Earth know how to act or how to function in case of free fall (Mobus & Kalton, 2015). Moreover, they added that “...*encoded knowledge of how to act is modified moment to moment by an information flow... which arrives as some level of structural modification. This structure-encoded knowledge-behavior linkage, mediated by the continual flow of information, becomes the changing world of process*” They also exemplified that processes in physics are relatively deterministic and more likely to be foreseen compared to sociology / psychology. Mental models of individuals can be modified as a result of informational flow from outside world; however, encoded knowledge in large-scale organizations like societies are more resilient to changes compared to the individuals.

Within the context of water system, there are both physical and mental way of encoded knowledge and processing information since the elements of water system includes both physical and structure of water as well as living things’ mental models. In a physical manner, water cycle knows how to function. The water molecules are moving constantly up and down in all over the world in different phases like solid, liquid, and gas. If global temperature increases i.e. global warming, water cycle modifies its rate of evaporation, precipitation etc. In a mental manner, for example, people know that the amount of water on Earth is relatively constant and water cycle provide water for living things to survive. However, when the depletion of water resources arises and unsustainable water use lead to many problems, the questions of “how much water do we have?” or “how much water should every person use for the sustainability of water on Earth?” are emerged. Then, with the help of scientific knowledge, the mental models of people have started to be modified by this informational flow. Correspondingly, to overcome these challenges, different solutions came to the agenda even though our society is still resistant to change water consumption habits. Nevertheless, we are now aware that we are not water-rich in this planet and we should use water more efficiently. Or social system encodes this knowledge and react based on this informational flow.

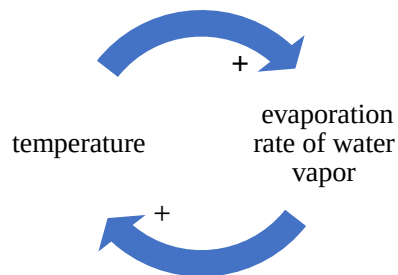
### *Principle 8. Systems Have Regulation Subsystems to Achieve Stability*

Systems tend to keep system integrity and function steady state over time and CAS are generally regulating themselves by using feedback loops mechanisms (Mobus & Kalton, 2015). They also outlined that CAS are modifying more than one property due to inherently being complex while regulating themselves. As a result, multiple regulations in CAS usually have side effect that are rarely predictable.

There are two feedback loops, negative (or balancing) loops and positive (or reinforcing) loops (Sweeney, 2001), that described in systems science and systems thinking studies. Reinforcing (or positive) loops mostly resulted in exponential growth or exponential decay when a change of A in a system cause a change of B in the same direction and this also, in turn, generates more change of A (Kirkwood, 1998). An example can be shown as following:

**Figure 5.2**

*An Example for Reinforcing Loop*



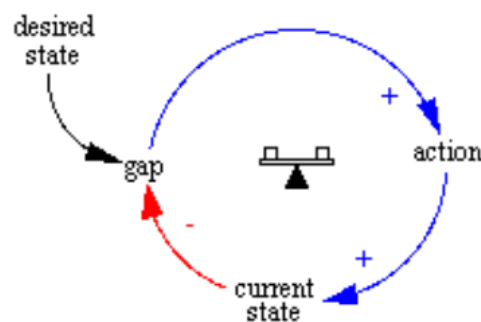
In Figure 5.2, it was summarized that increase in global temperature led to an increase in evaporation of water vapor which is one of the greenhouse gases. Since water vapor is a greenhouse gas, it also led to an increase in temperature, in turn, and this cycle becomes a reinforcing cycle.

On the other hand, balancing loops intends to reach a desired goal from the current state (Kirkwood, 1998). As an example, in Figure 5.3, the difference between desired

and current state determines the size of “gaps” that stimulate an action. If the action enhances to current state and this decrease the gap, stimulation for an action will also decrease and the system will reach a stability. The basic diagram can be shown as following (<http://www.systems-thinking.org/intst/int.htm>):

**Figure 5.3**

*An Example for Balancing Loop*



Within the context of water system, we can exemplify Figure 5.3 as following: increase in water vapor leads to an increase in cloud formation. As clouds are essential to reflect sunlight into the space. Therefore, incoming sunlight to the Earth decrease and this provides a balance for temperature. We can name “current state” as rise in temperature and “desired state” as cooling the temperature. Then the “action” will be cloud formation within the water system. Even though these diagrams in Figure 5.2 and Figure 5.3 seems to be simple for representing real life issues, there are interacting loops in reality combining these two loops.

#### *Principle 9: Systems Contain Models of Other Systems*

To enable interactions with other systems, systems generally have *models* of other systems that they interact. Model in this context refers to “*simplified version of reality*”. For example, living things have structural model of their surroundings so that



they are able to live and survive (Mobus & Kalton, 2015). Examples are given by them as following:

- Our mental models model the world that we live in
- Maps are models that we create to be able to locate and navigate ourselves
- The distribution of charges in the molecules models the other molecules that they are likely to produce compounds as a result of chemical reaction.
- People who are fishing model the prey's lunch to hunt them

All of the examples that is given above have a common characteristic: one system models the other system to have interaction with them. Within the context of water system, the researcher of this study gives following examples:

- Human beings imitate the water cycle to provide drinking water in cities
- Our brains model the natural water cycle to understand its working principles

These examples are some of the indicators that water system has different models of other systems to interact with them.

*Principle 10: Sufficiently Complex, Adaptive Systems Can Contain Model of Themselves*

All living organisms have models of themselves, “*self-conscious images of who and what they are that inform and guide their activity*” (Mobus & Kalton, 2015). From the DNA as a self-model to mental models in the brains, these self-models are fundamentally practical, provide codes of behavior that help system interactions. Mobus and Kalton also added that imprecise models fail to function properly and result in problems. As an example, dysfunctional models in our minds creates problems between society and environment. Within the context of this study, we can exemplify that dysfunctional interaction between society and environment leads to problems in

water system such as water pollution, water scarcity, and unsustainable water use. According to Mobus and Kalton, the reason for dysfunctionality is rooted from inaccurate models of systems in our mind.

#### *PR11. Systems Can Be Understood*

Systems can be understood by humans by building models and testing them to grasp the complexity of the world (Mobus & Kalton, 2015). Here, Mobus and Kalton articulated that our mental model for a system is simplified but not the complete version of the system itself. These models in our mind are subject to change as we test them and experience their functionality. Therefore, modeling is an iterative process lasting forever. Within the context of the study, students' drawings as well as their responses provide some indicators about their mental models on the water system. They may have both conceptual models on the working principles of the natural water cycle as well as how living organisms use water.

#### *PR12. Systems Can Be Improved*

In this principle, Mobus and Kalton (2015) denoted that an improvement in a system only if a specific function achieves a specific interest. In other words, in a nested and interwoven system, one action can be regarded as “improvement” but at the same time it can be also a degradation due to its unintended effects. Mobus and Kalton exemplified this principle as following (p.29):

If I say it's great to have a new highway, someone else can always bring up sacrifice of land, air quality, noise, or others of a virtually unlimited (and equally systemic) number of ways in which the improvement might also be considered a degradation. Systems science will furnish a framework for thinking through these issues.

### **5.2.2 Human Systems as a Complex Adaptive System**

Since human beings are also subsystems of all the systems both as an individual and as a group of people (Henning & Chen, 2012), their beliefs, information, values, ideas, and goals should be also taken into account while constructing systems literacy in

water system context. In this study, researcher integrated human aspect into the principles from *PR7* to *PR12* since (1) human beings are sufficiently complex and adaptive system and contain model of themselves in their mind as mental models; (2) systems can be understood by humans but those understandings intertwined with their beliefs, values, goals, and ideas; and (3) systems can be improved by humans due to the same reasons in (2).

### **5.2.3 Three Elements of Systems Literacy in Water Context**

In this part, systems literacy of middle school students within the context of the water system were elaborated based on the three elements of systems literacy. Moreover, supplementary definitions were also provided for the constructs such as knowledge, belief, motivational orientation etc.

In the light of definition of systems literacy given in the previous section, the content of the middle school curricula pertinent to water concepts and principles of systems science, systems literacy of middle school students within the context of the water system can be defined as following:

For students who complete their middle school degree, systems literacy in the context of the water system could refer to be about being able to perceive water system(s) that they interacted with and the courses of their actions that interfere with water system(s). This perception encompasses not only the level of knowledge about the general principles of water systems but also includes cultural components as well as a set of other psychological constructs that might have a role in understanding and engaging water system(s). A typical systems literate individual is expected to be sufficiently critically systems literate that relies on both adequate level of functional and cultural systems literacy in the water system context. What is more, systems literature individuals are the ones who could be able to aware of the fact that human systems have a potential to influence both the water system mechanisms on the planet and individual and collective human behavior in this system.

Based on this description, three elements of systems literacy in water system context were elaborated in the subsequent sections.

#### **5.2.3.1 Functional Systems Literacy in Water System Context**

Functionally systems literate students who are graduated from middle schools are expected to describe natural water cycle and to identify other living things as well as human system in terms of their use of water and probable effects on the water system without drawing any implication for sustainable water consumption.

Within the context of the functional systems literacy, types of knowledge and nature of the incorrect responses were included to be examined. For the types of knowledge, Marzano and Kendall's definitions (2008) for declarative and procedural knowledge were used as framework for the knowledge construct. Declarative knowledge refers to a content knowledge related to rote memorization of the basics. It mainly deals with the question of "*what*". On the other hand, procedural knowledge involves "*how does it work?*" question. Every procedural knowledge begins with declarative knowledge and this makes a hierarchical relationship between them. Within the context of this study, these two knowledge domains were used. The researcher of this study expected that system-literate individuals in water context could be able to organize their ideas based on the principles and generalizations of a system. Moreover, they need to know some vocabulary terms, facts, and the possible time sequence in the water system. In terms of mental procedures, individuals would be able to familiar with some processes within the system, its components, and their interactions.

To explore the nature of the incorrect responses, Taber's framework of 'Inclusive View' which defends that both 'knowledge-in-pieces' and 'alternative conceptions' could be found in students' minds. While the former framework assumed that these conceptions are inconsistent and labile emerged in the case of probing, the latter one claimed that alternative conceptions are resistant to change even if after the instruction.

#### **5.2.3.2 Cultural Systems Literacy in Water System Context**

By saying local context, the researcher of this study aimed to refer local water system and its layers in participants' hometown. Culturally systems literate students who are

graduated from middle schools are expected to describe local water system layers one by one (elements of local water system, drinking water and wastewater treatment system in their hometown, human system in terms of use of water and its effects on the local water system) without drawing any implication for sustainable water consumption. To understand the nature of their knowledge, the frameworks (Marzano & Kendall, 2008; Taber, 2008) used in functional systems literacy were also used in this element of systems literacy in the context of water system.

### **5.2.3.3 Critical Systems Literacy in Water System Context**

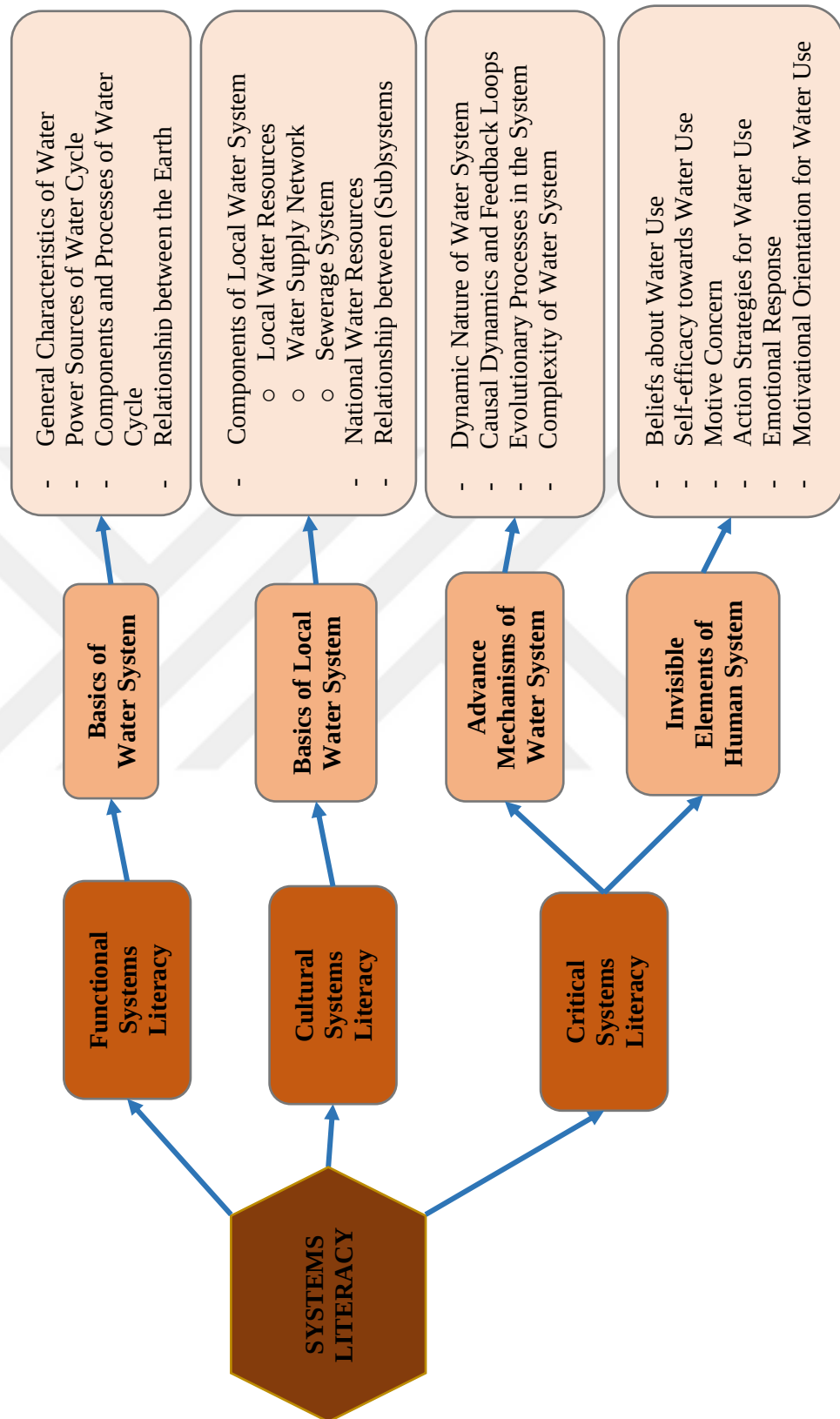
Stables (1998) argued that critical literacy demands both functional and cultural literacy. In a similar manner, critically systems literate students who are graduated from middle schools are expected to have adequate level of functional and cultural systems literacy in water system context. Apart from this prerequisite, critically systems literate students who are graduated from middle schools are expected to (1) grasp water system's dynamic nature on multiple time scales (2) be aware of potential effects of different time scales; (3) explain different types and levels of complexity in water cycle/system which can be the basis for disruption or failure; (4) describe evolutionary processes of water system when it interacts with human systems; (5) explain feedback loops which are for regulating subsystems to provide maintenance; (6) predict that humans may interfere with the water system; and (7) appreciate that water system on Earth can be understood and improved.

In addition to these advance mechanisms in the water system, invisible elements of human system were also regarded within the context of critical systems literacy in water system because their characteristics potentially interferes with the water system mechanisms as outlined in the previous chapters. These constructs are also potentially interacted with individuals' water consumption behaviors. Consequently, the constructs of beliefs, action strategies, self-efficacy beliefs, motive concerns, emotional response, and motivational orientation for maintaining a system were also included to indicate individuals' critical systems literacy in water system context.

Accordingly, critically systems literate students who are graduated from middle schools are expected to (1) provide plausible action strategies pertinent to the maintenance of water system; (2) monitor their actions' clarity and accuracy; (3) explain their motive concerns, if any, on the maintenance of the water system; and (4) explain their motivational orientations, if any, toward sustainable water use. At this point, it is noteworthy that water consumption behaviors can be considered in two dimensions: (1) being able to differentiate direct use of water, and indirect (hidden) use of water; and (2) being able to explain the mechanisms of local water system. For example, middle school students might not be able to aware of the amount of water they consume, if they do not know their hidden use of water. In a similar manner, having inadequate level of knowledge on their local water system could inhibit students' critical systems literacy. Accordingly, their beliefs, action strategies, self-efficacy beliefs, emotional response and even motivational orientations could be formed based on a fallacy and result in a limited level of critical systems literacy in water system context. In short, conceptual model for systems literacy based on the conceptual research was visualized by the researcher as given in Figure 5.4.

**Figure 5.4**

*Conceptual Model of System Literacy in Water System*



### **5.3 Middle School Students' Systems Literacy in Water Context**

The purpose of this section is to summarize the empirical findings of the study. The analysis of the responses was portrayed by means of categories in systems literacy summarized in [Table 4-11](#). In this section, each of the four cases was reported separately within the context of multiple case study. Then, cross-case analysis was given.

#### **5.3.1 Case 1: Eren**

Eren was born in 2005. He is a ninth-grader male student in a science public high school located in an inland city. His school is one of the high schools that accept students among the top 0.09% of the applicants of national entrance exam. Eren's entrance exam score was 500 out of 500 points and he was sharing his ranking with other 564 students nationwide. In total, 1,025,607 students took the national entrance exam in that year (MoNE, 2019).

Eren's mother is currently housewife but she was electrical and electronics engineer; his father is a doctor. Their single-family house is located one of the most crowded towns in the capital city. There is no natural water resource such as sea, lake or river around their house.

During his middle school, he only conducted an electrolysis experiment related to water. Apart from this, he had no other specific activity or interest in water context. In the ninth grade before I collected data from him, the rate of water in living organisms was taught in his biology course. On the other hand, his school offers variety of extracurricular activities which may interacted with Eren's systems literacy in water context. He reported that he participated in three different seminars which was related to (1) discovery of aquaporin water channels in the cell membranes; (2) introduction to systems science; and (3) sustainable development goals. During the data collection period, he was preparing a thermal storage project in which he used water.



I worked with Eren in two sessions. The responses of Eren through the conception test, first drawing task, and interview questions reflected some indicators related to his systems literacy. The analyses of his responses were given below under the elements of functional systems literacy, cultural systems literacy, and critical systems literacy.

#### **5.3.1.1 Eren's Functional Systems Literacy**

The analysis of Eren's responses in conception test, first drawing task and interview phase 1 revealed his functional systems literacy in five categories as (1) general characteristics of water; (2) power sources of water cycle; (3) components of water cycle; (4) processes of water cycle and (5) relationship between the Earth systems. [Table 5-1](#) indicated codes and categories for his functional systems literacy in water context. All codes and categories were given in Appendix C. Note that 'pale codes' represented the ones that did not emerge from Eren's responses.

##### **5.3.1.1.1 General Characteristics of Water**

The first category in explaining Eren's functional systems literacy was general characteristics of water. Eren's answers for the questions for this session were given by means of quantity of water, its cyclic nature, relational responsiveness and water and living organisms.

##### ***Quantity of Water***

Quantity of water refers to (1) compare the proportions of water stored in different water resources (2) state that almost all the amount of water does not change on Earth. Eren was the only participant that mentioned about the percentage of water covering on Earth. He stated that three quarters of the Earth is covered by water which was a closer approximation to the correct answer. Approximately 71% of the Earth is covered by water (USGS, 2019). On the other hand, Eren correctly responded that most of the water on Earth is found in oceans in his conception test (please see ).

**Table 5-1***Themes, Categories and Codes of Eren's Functional Systems Literacy*

| <b>Theme - Basics of Water System</b>                         |                                     |
|---------------------------------------------------------------|-------------------------------------|
| <i>Category 1: General Characteristics of Water</i>           |                                     |
| FGC11: Quantity of Water *                                    | FGC14: Water and Living Organisms   |
| FGC12: Cyclic Nature                                          | FGC15: Relational Responsiveness    |
| FGC13: Properties of Water                                    |                                     |
| <i>Category 2: Power Sources of Water Cycle</i>               |                                     |
| FPS21: Sun                                                    | FPS23: Gravity                      |
| FPS22: Wind**                                                 |                                     |
| <i>Category 3: Components of Water System</i>                 |                                     |
| FC31: Plant                                                   | FC317: Cloud                        |
| FC32: Sun                                                     | FC318: Rain                         |
| FC33: Water                                                   | FC319: Snow                         |
| FC34: Animal                                                  | FC320: Fog                          |
| FC35: Human                                                   | FC321: Hail                         |
| FC36: Ocean                                                   | FC322: Freshwater                   |
| FC37: Sea                                                     | FC323: Ice                          |
| FC38: Water Vapor                                             | FC324: Well                         |
| FC39: River                                                   | FC325: Lake                         |
| FC310: Glacier                                                | FC326: Stream                       |
| FC311: Spring                                                 | FC327: Dew                          |
| FC312: Soil                                                   | FC328: Algae                        |
| FC313: Wetland                                                | FC329: Creek                        |
| FC314: Rock                                                   | FC330: Puddle                       |
| FC315: Groundwater                                            | FC331: Mountain                     |
| FC316: Aquifer                                                |                                     |
| <i>Category 4: Processes of Water System</i>                  |                                     |
| FP41: Evaporation                                             | FP410: Surface flow                 |
| FP42: Condensation                                            | FP411: Melting                      |
| FP43: Sublimation                                             | FP412: Freezing                     |
| FP44: Evapotranspiration                                      | FP413: Frosting                     |
| FP45: Respiration                                             | FP414: Dissolution                  |
| FP46: Precipitation                                           | FP415: Transpiration                |
| FP47: Penetration                                             | FP416: Capillarity                  |
| FP48: Infiltration                                            | FP417: Photosynthesis               |
| FP49: Underground flow                                        |                                     |
| <i>Category 5: Interactions among the Earth (Sub)Systems*</i> |                                     |
| FRES51: Hydrosphere—atmosphere                                | FRES55: Hydrosphere-anthroposphere  |
| FRES52: Hydrosphere—geosphere                                 | FRES56: Water cycle- nitrogen cycle |
| FRES53: Hydrosph. (continental)—hydrosph. (marine)            | FRES57: Water cycle- oxygen cycle   |
| FRES54: Hydrosphere—biosphere                                 | FRES58: Water cycle – carbon cycle  |

\*black codes: emerged from Eren's responses

\*\*pale codes: not apparent in Eren's responses

In his interview, he elaborated this phenomenon as following:

*... (the conversation continues before the excerpt) ...*

This unconscious use doesn't lead to a change in the total amount of water on Earth since living organisms couldn't do that because of the Newtonian law: nothing is lost, nothing is created, everything is transformed. We don't have a chance to give it out of the space. We only affect its rate of phase change...

*... (the conversation continues after the excerpt) ...*

The analysis of his answers in different forms of questions (conception test items, interview questions) revealed that he identified the highest proportion stored in the oceans. Moreover, he knew that the amount of water is almost constant on Earth. He revealed his correct declarative and procedural knowledge while he was explaining. The only exception is that he failed to name the scientist, Antoine Lavoisier, discovered the law of conservation of mass.

### ***Cyclic Nature***

For obtaining information about his notion on the cyclic nature of water, the first drawing task, conception test, and interview questions were analyzed. In his drawing, cyclic nature of the water was not observed. Even though water evaporated and precipitated, its journey followed a single path starting from a water body to the sea.

After the first drawing task ended, he explained how water cycle occurs as following:

Eren: Assume that we have a water resource which can be a sea or an ocean. Water evaporates with the help of heat... After that, condensation occurs because there is a cooling happening there. Thanks to the condensation, it precipitates as rain, fog, or dew. It transforms into water again. Then precipitated water reaches to another sea again.

Even though his drawing did not indicate a cycle, his explanation of his drawing included indicators for his notion of cyclic nature. He explained that water evaporating from a water resources, for example, might end up in another water resources such as a sea. However, his responses indicated that water only evaporates from the surface water resources. He also failed to include solid state of water and groundwater while he was explaining how water cycle occurs.

**Figure 5.5**

*Eren's Drawing of Water Cycle*



In conception test, Eren chose the answer that there is no starting/ending point of the water in the conception test (please see ). In the later parts of his interview, he explained the concept of starting/ending point as following:

Eren: The starting point of the water cycle could be the Big Bang. Gases had transformed from one to another with fission and fusion. After the forming of the Earth had been completed, I think first water vapor precipitated as rain by condensation. Then water resources appeared on the Earth surface and it evaporated, and the cycle was formed.

Interview: I see you mentioned the history of water cycle. So, what about the recent form of water cycle? Is there any starting/ending point?

Eren: No. It cycles repeatedly. Evaporated water condenses at somewhere.

During the interview phase 3, as he did not know the wastewater treatment techniques, he formed an *in-situ* answers that it is not feasible to do wastewater treatment in the cities. Accordingly, he made an inference that polluted water has a slower rate of evaporation and therefore, the amount of water in the water cycle would be affected. He presumed that unless water evaporates, it could not be considered within the water cycle. This conversation will be given under the section of “Advance mechanisms of the water system”. All these responses acquired from different data collection tools indicated that he had fully correct declarative knowledge and partially correct procedural knowledge on the cyclic nature of the water system. He had also an *in-situ* response that “the amount of water in the water cycle decreases because of water pollution”.

### ***Relational Responsiveness***

This category was traced through implicit questions within the interview to explore their notion within the context of the water system. Participants chose to explain relational responsiveness of the water system within the context of either living or nonliving subsystem’s reactions. Eren was one of the participants to explain relational responsiveness. The conversation was given below.

Interviewer: ... Does water system react when a problem occurs? Why or why not?

Eren: It reacts... Of course, this reaction is not like human-brain-reaction but rather action-reaction. If we act, it reacts. For example, as I said earlier, due to our action (*referring man-made greenhouse effect*), its reaction will be the increase in the rate of evaporation. Then it condenses more. This is a reaction because of our action. After a while, drought or flood may emerge due to our actions.

Interview: So, you said that it does not have brain. I wonder how the water system decides this action-reaction processes?

Eren: It is by default. The water system already has evaporation and condensation process. The only thing we do as humanity to increase the rate of them. It’s like increasing the number of substances in a chemical reaction. Chemical reactions are default, but we increase inputs and we get more outputs. But the outputs in the water system context have catastrophic consequences.

The analysis of his responses revealed that he reflected his declarative and procedural knowledge on the relational responsiveness of the systems in water context. However,

they were classified as partially correct since Eren failed to explain the nature of the complex organism's reactions in the water system to change in its environment.

### ***Water and Living Organisms***

Participants explained the role of living organisms in the water system as well as their use of water for different purposes within the context of this study. Eren mentioned some interactions between the water and the living organisms, which are namely some microorganisms, plant, animal, and specifically, humanity. He was the only participant that considered the some of the microorganisms related to the water system.

While he was explaining the mutual interactions between the living organisms and the water system, he stated that

Living organisms use water for their bodies. They perform transpiration to balance their body heat. On the other hand, people use water vapor in the air to help balance in osmotic pressure. Maybe, a water vapor released from our body, let's say, give heat to a plant since that water vapor gives heat during condensation

The statement revealed that he had declarative knowledge that living organisms use water in their bodies. On the other hand, he mentioned correctly the mechanisms of respiration, photosynthesis, and transpiration in living organisms in different instances during the interview. In terms of humanity, he explained not only the processes of respiration and transpiration, but also the positive and negative effects of human use of water on the water system. Overall, he had declarative knowledge on the interactions between the water and the living organisms. In terms of procedural knowledge, he explained the processes in detail which will be given in the subsequent sections.

#### **5.3.1.1.2 Power Sources of Water Cycle**

Power sources of the water cycle was traced in all tasks during the data collection. Eren mentioned sun and gravity as two of the power sources. He failed to mention

wind as a power source. In his drawing, no power source was indicated. During the interview, he stated that sun was the only the power source as *“Temperature and the pressure... the pressure forms due to the temperature. This acts as an activation energy for the water cycle... The source of the temperature and the pressure is sun”*. Unlike his drawing and the responses during the interview, he selected correct answers in the conception test. In conception test, Eren responded three questions related to two power sources as sun and gravity (please see ).

To sum up, he correctly responded all three questions in conception test. However, he only mentioned the sun during the other forms of data collection. Still, the data revealed that he stated sun and gravity as two of the power sources and correctly explained (or chose the best alternative) the processes.

#### **5.3.1.1.3 Components and Processes in Water System**

Within the context of the components of water system, Eren mentioned 18 of 31 components in the conception test, his drawings as well as during the interview. In the conception test, he identified ocean as the biggest sources of water on Earth. In his drawing ([Figure 5.5](#)), he used the components such as water, sea, clouds, rain, and human beings. On the other hand, he mentioned animals, soil, sun, algae, water vapor, plants, dew, fog, glaciers, river, lake, and groundwater during the interview in different occasions.

In terms of processes, he identified seven processes of out 17. In his drawing, he indicated the processes of evaporation, condensation, and precipitation. On the other hand, he mentioned melting, respiration, photosynthesis, and transpiration during the

Eren reflected different components and processes in different data sources. For example, he did not include all the processes and components that he identified in the conception test within his drawing. In his interview, he exemplified other components and processes. Overall, he exemplified 18 components of water system during the interview. Additionally, he explained seven processes of water system. In terms of

procedural knowledge, he explained correctly all the seven processes in the water system which will be given in the subsequent sections.

#### **5.3.1.1.4 Interactions among the Earth Systems**

The analysis of Eren's responses emerged five different relationships among the Earth systems as (1) hydrosphere and atmosphere; (2) hydrosphere (continental) and hydrosphere (marine); (3) hydrosphere and anthroposphere; (4) hydrosphere and geosphere; and (5) hydrosphere and biosphere. Almost all of these relationships were mentioned by Eren through triple combinations and more. Each combination was given below.

The analysis of his drawing, interview, and responses of the conception test had some indicators about his understanding of the relationship between hydrosphere and atmosphere. In his drawing, he indicated evaporation, condensation, clouds, and precipitation. In terms of cloud formation, Eren explained how clouds form in his interview as *"Clouds are actually a concentration of water vapors in the stratosphere. They are basically condensed form of water vapor"*. Even though his responses related to the ingredient of the clouds (water droplets) was partially correct, he did not correctly locate the place of the clouds within the layers of atmosphere.

Similar with his explanation, he had vague responses for the clouds in the conception test (please see ). For the first question, he chose more than one alternative. Choosing more than one alternative revealed that he had lack of knowledge on the cloud formation. For the other question, he selected that *"the process of evaporation explains best the cloud formation"* since *"water evaporating from the earth's surface goes to the clouds"*. This response was an indicator of having alternative conception of cloud formation since clouds are not entities that water vapor goes into them. In short, it can be summarized that he was able to reveal partially his declarative knowledge. Nonetheless, he failed to explain its processes which indicated that he had naïve understanding on how clouds form.



The relationships among atmosphere, hydrosphere (continental), anthroposphere, and hydrosphere (marine) was detected in his drawing and interview. Figure 5.5 revealed that precipitated water flows to the sea. When I asked, “*Is there any other system hidden in your drawing that might have an interaction with the water system?*” during the interview, he integrated atmosphere into anthroposphere, hydrosphere (continental) and hydrosphere (marine) as following:

I can give examples for an artificial system. Imagine that there is a closed vessel (*referring the storage tank in his drawing*). If we increase the pressure, the movement will increase. If we put a turbine over here, we produce electricity. Let’s put a generator also... Water system could affect that artificial system.

... (*the conversation continues after the excerpt*) ...

One another thing is that rainwater can be collected through channels and pipes (*referring the icons in his drawing*). They could be accumulated and transferred to the sea. What is more, we can put algae bacteria within the channels so that the water will be enriched in oxygen.

The analysis of his responses reflected that he stated his declarative knowledge on the relationship between these four (sub)systems. In terms of procedural knowledge, he elaborated the artificial systems but did not give more detail about the other systems mentioned above.

The third combination emerged from the analysis was related to the effect of water system on human life as well as geosphere: “*Water system affects the human life. For example, farmers need rain for their soil. The rate of condensation in the water system affects the soil fertility*”. These sample excerpt revealed that he stated the possible dual interactions among the hydrosphere, atmosphere, anthroposphere and geosphere. In terms of procedural knowledge, he elaborated the artificial systems but did not give more detail about the effects of water system on farmer’s life.

In addition to these, he also mentioned the interactions of hydrosphere, atmosphere, and biosphere as following:

I think it is global warming. If a water resource becomes more warmer than before, then the rate of evaporation will increase which affects the living organisms

negatively. If evaporation rate intensified, then oxygen rate in water decreases and their life will be in danger.

Overall, he revealed his declarative knowledge on this interaction. He did not elaborate how oxygen rate decreases with the evaporation and what “in danger” refers to.

In brief, when we examine [Figure 5.5](#) as well as his responses in different data collection instruments, we can summarize his functional systems literacy as following table. [Table 5-2](#) reviewed his knowledge not only in terms of level of correctness but also labeled that specific knowledge as declarative or procedural. Additionally, table also elaborated the incorrect responses as either it is a consistent and stable or it was produced *in-situ* which is inconsistent and unstable.

#### **5.3.1.1.5 Mapping the Interactions of the Categories in Eren’s Functional Systems Literacy**

To explore the interactions among the categories in FSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. Figure 5.6 revealed the map was given below. The details of the mapping were given under the methodology chapter.

Based on the content analysis of this section, I can summarize Eren’s functional systems literacy in water context as following:

- [Table 5-2](#) revealed that Eren had mostly declarative knowledge on the basic mechanisms of the water system.
- In terms of procedural knowledge, he had relatively good understanding on the working principles of the water system.
- At some points while examining the procedural knowledge, he had some misconceptions.
- [Figure 5.6](#) revealed that *Components of Water System*, *Processes in Water System*, and *Relationship between the Earth Systems* had most interactive categories among

the others. In other words, while Eren was talking about the basics of water system, he mostly used these three categories.

- *Power Sources of the Water Cycle*, on the other hand, was the most limited category among the others. There was a weak integration of the power sources into the other categories of FSL to explain the basics of the water system.

In the next section, Eren's cultural systems literacy in water context will be given.



**Table 5-2**

*Summary of Eren's Functional Systems Literacy in Water Context*

| Categories / Codes*                                      | Declarative /<br>Procedural | Fully Correct<br>Statement(s) | Partially<br>Correct<br>Statement(s) | Incorrect<br>Statement(s) |              |
|----------------------------------------------------------|-----------------------------|-------------------------------|--------------------------------------|---------------------------|--------------|
|                                                          |                             |                               |                                      | Consistent                | Inconsistent |
| General Characteristics<br>of Water                      |                             |                               |                                      |                           |              |
| Quantity of Water                                        |                             |                               |                                      |                           |              |
| 1. Proportion of<br>water resources                      | Declarative                 | ✓                             |                                      |                           |              |
| 2. Change in amount of<br>water on Earth                 | Procedural                  | ✓                             |                                      |                           |              |
| Cyclic nature                                            | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  |                               | ✓                                    |                           | ✓            |
| Water and Living<br>Organisms                            | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  | ✓                             |                                      |                           |              |
| Relational<br>Responsiveness                             | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  | ✓                             |                                      |                           |              |
| Power Sources of Water<br>Cycle<br>(2 out of 3) **       | Declarative                 |                               | ✓                                    |                           |              |
|                                                          | Procedural                  | ✓                             |                                      |                           |              |
| Components of the<br>Water System<br>(18 out of 31)      | Declarative                 |                               | ✓                                    |                           |              |
| Processes of the Water<br>System<br>(7 out of 17)        | Declarative                 |                               | ✓                                    |                           |              |
|                                                          | Procedural                  | ✓                             |                                      |                           |              |
| Relationship between<br>the Earth System<br>(5 out of 7) |                             |                               |                                      |                           |              |
| Hydrosphere –<br>Atmosphere***                           | Declarative                 |                               | ✓                                    |                           |              |
|                                                          | Procedural                  |                               | ✓                                    | ✓                         |              |
| Hydrosphere – Biosphere                                  | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  |                               | ✓                                    |                           |              |
| Hydrosphere –<br>Anthroposphere                          | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  |                               | ✓                                    |                           |              |
| Hydrosphere<br>(continental) -<br>hydrosphere (marine)   | Declarative                 | ✓                             |                                      |                           |              |
|                                                          | Procedural                  |                               | ✓                                    |                           |              |
| Hydrosphere -<br>Geosphere                               | Declarative                 | ✓                             |                                      |                           |              |
| TOTAL (n)                                                |                             | 13<br>(8 D,5 P)               | 9<br>(4 D, 5 P)                      | 1<br>(1 P)                | 1<br>(1P)    |

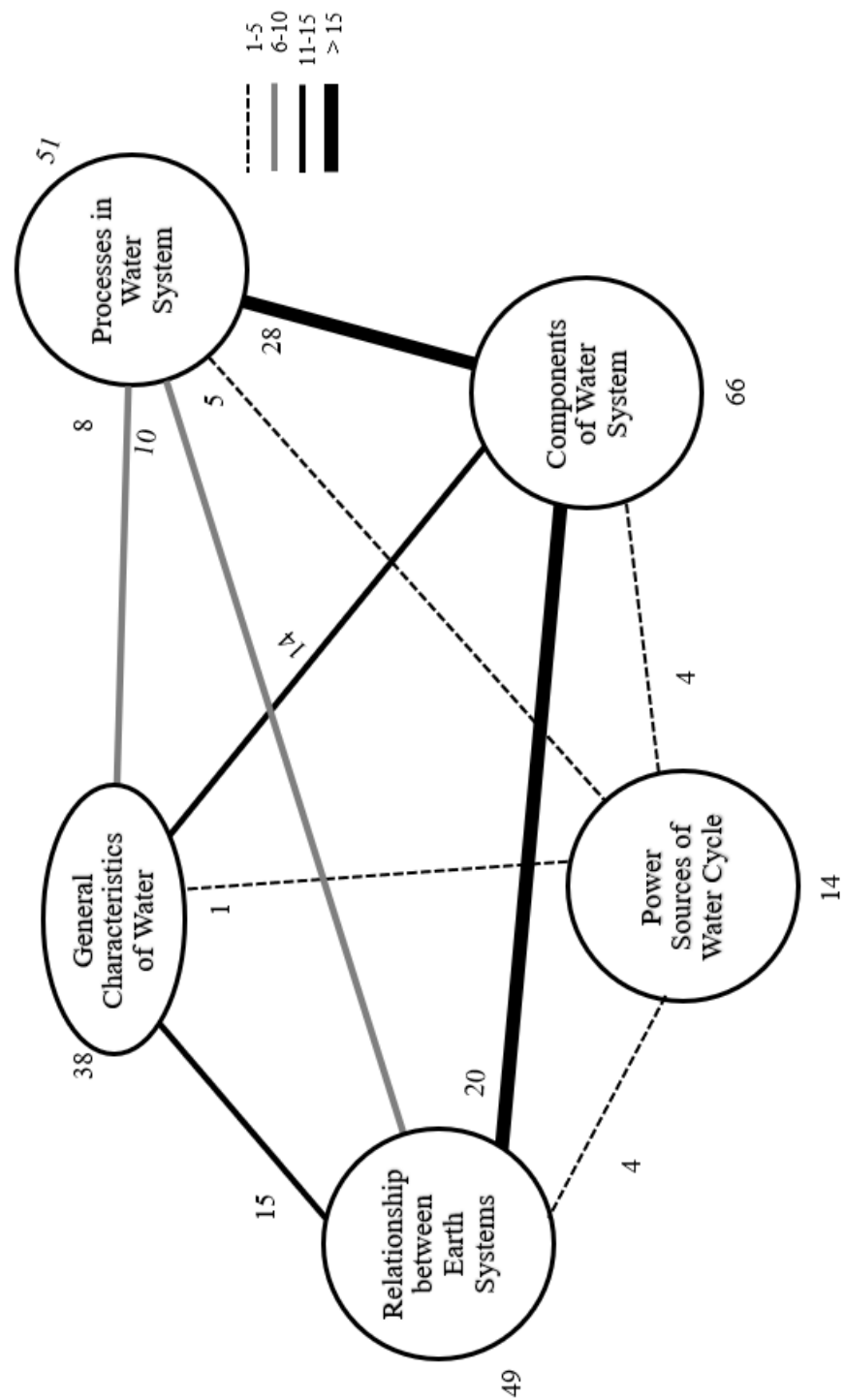
\* Not all categories/codes were given in this table since some of them were not observed

\*\* Even though participant has partially correct response in declarative knowledge, (s)he has fully correct response for the procedural knowledge.

\*\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception.

**Figure 5.6**

*Mapping the Interactions among the Categories of Eren's Functional Systems Literacy*



### **5.3.1.2 Eren's Cultural Systems Literacy**

Cultural systems literacy was centered around the basics of the local water system within the context of this study. Accordingly, the second drawing task and phase 2 interview questions on CUSL were analyzed to portray participants' cultural systems literacy. The content analysis revealed three categories as (1) Components of Local Water System (LWS); (2) National Water Resources (NWR); and (3) Relationships between LWS and (Sub)systems. Additionally, the category of components of LWS had three sub-categories needs to be elaborated as (1) Local Water Resources and (2) Water Supply Network; and (3) Sewerage System. In this section, these categories and subcategories were covered in detail. [Table 5-3](#) indicated the categories and codes of his cultural systems literacy in water context.

#### **5.3.1.2.1 Components of Local Water System**

Components of LWS was examined through the second drawing task as well as phase 2 interview questions. Within the context of the second drawing task, the researcher asked Eren to draw his local water system. However, his drawing was dominated by domestic water use. His notion related to the other components of water system, on the other hand, were traced through the interview questions. His second drawing was given in [Figure 5.7](#).

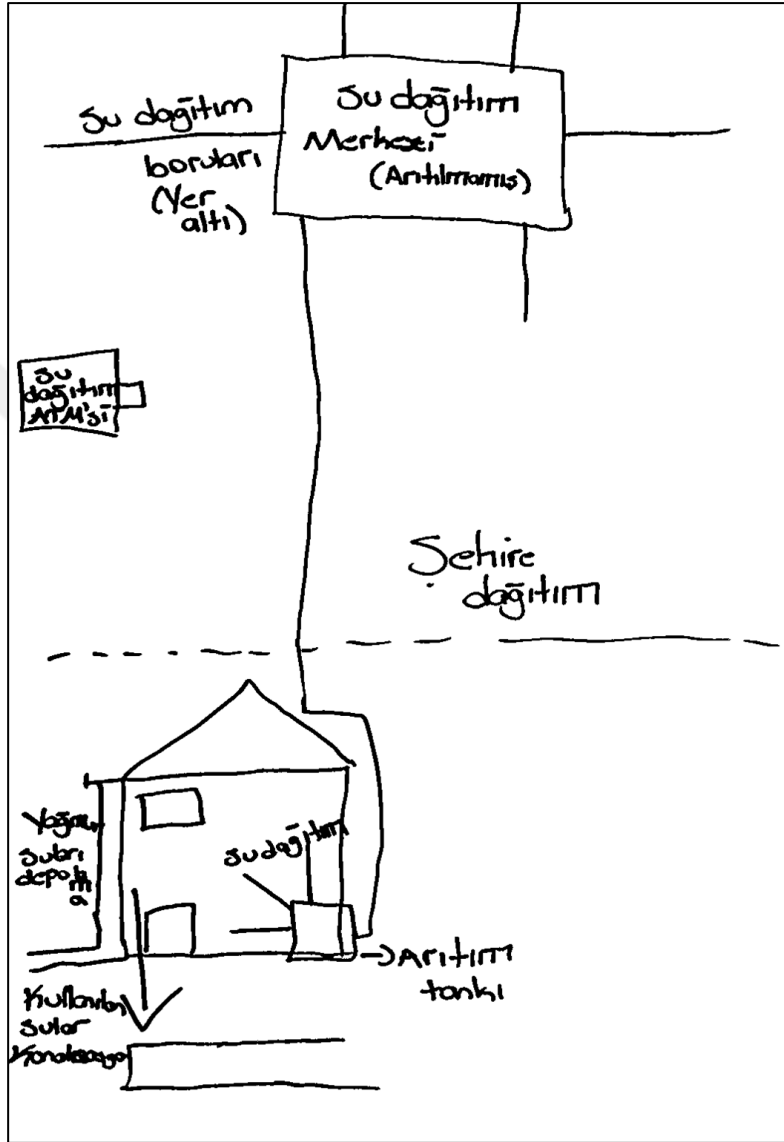
His drawing included some of the elements of water supply network (WSN). During the interview, he also mentioned animals, plants, human beings, microorganisms, and two of the local water resources which covered overall the components of LWS given in the codebook. Sewerage system, WSN and LWR will be given under the subsequent section since they require further classifications.

**Table 5-3***Categories and Codes – Eren’s Cultural Literacy*

| <b>Theme: Basics of Local Water System (LWS)</b>                               |                |                       |                                |
|--------------------------------------------------------------------------------|----------------|-----------------------|--------------------------------|
| <b>Category 1: Components of LWS</b>                                           |                |                       |                                |
| Animal                                                                         | Human being    | Local Water Resources | Sewerage System                |
| Plant                                                                          | Microorganisms | Water Supply Network  |                                |
| <i>Sub-Category 1.1: Local Water Resources</i>                                 |                |                       |                                |
| <i>Sub-Category 1.1.1: Name of LWR</i>                                         |                |                       |                                |
| Lake Tuz                                                                       | Lake Eymir     | Çubuk Dam             | River Kızılırmak               |
| Lake Mogan                                                                     | Kurtboğazi Dam | Aegean Sea            |                                |
| <i>Sub-Category 1.1.2: Functions of LWR</i>                                    |                |                       |                                |
| Survival                                                                       | Recreational   | Energy source         | Industrial                     |
| Domestic                                                                       | Economical     | Religious             | Agricultural                   |
| <i>Sub-Category 1.2: Water Supply Network (WSN)</i>                            |                |                       |                                |
| <i>Sub-Category 1.2.1: Components in WSN</i>                                   |                |                       |                                |
| River                                                                          | Hail           | Pipe                  | Drinking Water Treatment Plant |
| Cloud                                                                          | Water Puddle   | Engineers             | Water Storage Facilities       |
| Freshwater                                                                     | Well           | Water ATM             | Fountain                       |
| Rain                                                                           | Dam            | Home                  | Groundwater                    |
| Snow                                                                           | Lake           | People                | Sea                            |
| <i>Sub-Category 1.2.2: Processes in WSN</i>                                    |                |                       |                                |
| Precipitation                                                                  |                | Water Distribution    |                                |
| Water Accumulation                                                             |                | Water Treatment       |                                |
| <i>Sub-Category 1.3: Sewerage System</i>                                       |                |                       |                                |
| <i>Sub-Category 1.3.1: Components in Sewerage System</i>                       |                |                       |                                |
| Pipe                                                                           |                | Receiving Environment |                                |
| Wastewater Treatment Plant                                                     |                |                       |                                |
| <i>Sub-Category 1.3.2: Processes in Sewerage System</i>                        |                |                       |                                |
| Wastewater Collection                                                          |                | Wastewater Treatment  |                                |
| <b>Category 2: National Water Resources (NWR)</b>                              |                |                       |                                |
| <i>Sub-Category 2.1: Current State of NWR</i>                                  |                |                       |                                |
| Water Resources Potential                                                      |                | Water Pollution       |                                |
| <i>Sub-Category 2.2: Name of NWR</i>                                           |                |                       |                                |
| Aegean Sea                                                                     |                | Mediterranean Sea     | Lake Van                       |
| Black Sea                                                                      |                | Marmara Sea           | Lake Dipsiz                    |
|                                                                                |                |                       | Uzungöl                        |
| <b>Category 3: Relationship among Local, National, and Global (Sub)systems</b> |                |                       |                                |
| LWS- WSN                                                                       |                | LWS -Biosphere        | LWS -Atmosphere                |
| LWS -Hydrosphere                                                               |                | LWS -Geosphere        | LWS - Anthroposphere           |

**Figure 5.7**

*Eren's Local Water System*



### **Local Water Resources**

Local water resources were examined by means of *name of LWR*, and *functions of LWR*. In terms of specific names and functions of LWR, Eren identified that Lake Tuz and Lake Eymir as two of the local water resources. Then, he explained the functions



of LWR as domestic, recreational, and survival. His statements related to these functions will be given in the next sections. Overall, Eren identified some of the LWRs in his hometown. In terms of the functions of LWR, he explained they were used as survival, recreational, and domestic purposes.

### ***Water Supply Network and Sewerage System***

In this context, how individuals model their local water supply network was examined. Correspondingly, mental models tried to be acquired through the second drawing task as well as responses to phase 2 interview questions. The analysis of their responses revealed two sub-categories as WSN and Sewerage System.

Eren explained where water coming from to her home as following:

Eren: I know from my mother. There is a water distribution ATM (*Automatic Teller Machine*) near our home. She goes there and pay some money to upload water on ATM card. I reckon that there is a water storage facility to distribute water to the homes via pipes. In my house, we use filter to drink water from the tap. Besides, there is also a pipe collecting rainwater from our roof.

... (*the conversation continues after the excerpt*) ...

Water may be treated before the distribution to our homes for example if it is hardwater.

Interviewer: So, what is the water resource of that provides water to your home?

Eren: I think it is coming from the groundwater resource.

The analysis of his responses indicated that Eren identified six components of WSN in his hometown. On the other hand, Eren explained the discharging process of wastewater as:

It goes to the sewer. But I have never thought this before... (*he thought a minute*) ... It could not be discharged to other water resources, so let's remove this option. I am not sure whether they accumulated somewhere or not because it would be an endless wastewater. The expenditure of treating the wastewater would be so high so it is not feasible... (*he thought two more minutes*) ... It is accumulated somewhere; this is my last decision...

The analysis of his responses revealed that Eren had limited amount of knowledge about the water systems at his hometown. He identified six components of WSN,

whereas he failed to identify any component of sewerage system. Among the components of WSN, he stated that groundwater was used for WSN which was not the case. Besides, he failed to include freshwater resources, water treatment plants, dams, and receiving environment. In terms of processes, he only identified water treatment, water accumulation, and water distribution for WSN, while wastewater collection was the only processes in sewerage system that he mentioned. Overall, he was not sure about his responses. No detailed explanation was given in terms of processes. The sources of information were mainly based on his observations and his mother.

#### **5.3.1.2.2 National Water Resources**

The responses related to national water resources (NWR) were classified into two categories as *Name of NWR* and *Current State of NWR*. Eren did not prefer to explain his notion related to national water resources with specific names. Instead, he mentioned them in general. For example, in terms of current state of NWR, he stated that “*I’ve heard on the news that Turkey is not one of those water-rich countries*” On the other hand, he did not explain in detail why Turkey is not one of the water rich countries. This finding indicated that Eren has declarative knowledge on the water resources potential of Turkey in terms of water-richness, but he failed to reveal procedural knowledge on this subject.

#### **5.3.1.2.3 Relationship between Local and Global (Sub)systems**

The analysis of Eren’s responses emerged four different relationship among local and global (sub)systems as (1) LWS-Hydrosphere, (2) LWS-Biosphere, and (3) LWS-Anthroposphere; and (4) LWS- Geosphere perspectives. Almost all these relationships were mentioned by Eren through triple combinations and more. Each combination was given below.

As I outlined in the functional systems literacy section, he responded that the total amount of water is almost constant on Earth and is cyclic in nature. However, when he was talking about what happens to the domestic wastewater, he stated following:

Even though this accumulated domestic wastewater evaporates and purifies a little bit, most of it does not continue cycling because its evaporation point (*referring boiling point*) changes. This means that it does not evaporate in natural setting compared to the clean water. Of course, the water continues cycling, but its initial amount decreases.

His responses related to his local water system revealed that he failed to assimilate his FSL to his local context. His misinterpretation revealed his notion on the relationship between her LWS in her hometown and hydrosphere.

During the interview, relationships among LWS, Biosphere, Anthroposphere, and Geosphere were mentioned as following:

Fishes use the dissolved oxygen within the lakes in my hometown. Water evaporated from these lakes is used by plants and they perform photosynthesis with the help of the water. Additionally, they also take water from their roots. Besides, lakes are suitable medium for microorganisms like algae bacteria. Lakes are also useful for the people. They create an aesthetic view for them. If they are clean enough, then municipalities might use it for drinking purposes.

His response indicated his declarative knowledge on the relationship among LWS, biosphere, anthroposphere, and geosphere. He explained partially the processes within those interactions. In brief, when we examine [Figure 5.7](#) as well as his responses in different data collection instruments, his cultural systems literacy were summarized as following table. [Table 5-4](#) reviewed is knowledge not only in terms of level of correctness but also labeled that specific knowledge as declarative or procedural. Additionally, table also elaborated the incorrect responses as either it is a consistent and stable or it was produced *in-situ* which is inconsistent and unstable.

#### **5.3.1.2.4 Mapping the Interactions of the Categories in Eren's Cultural Systems Literacy**

To explore the interactions among the categories in CUSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.8](#) revealed the map.

Cultural systems literacy of Eren in terms of local water system can be summarized based on the content analysis of this section as following:

- [Table 5-4](#) revealed that Eren had mostly declarative knowledge on the basic mechanisms of his local water system. He had limited amount of procedural knowledge about the basic mechanisms of his local water system.
- [Figure 5.8](#) revealed that *Components of LWS* and *Relationship between Local and Global Systems* had most interactive categories among the others. In other words, while Eren was talking about the basics of his local water system, he mostly used components of LWS and its relationship among the other systems.
- *National Water Resources*, on the other hand, were the most limited categories among the others. He integrated them rarely into the other categories of CUSL.

**Table 5-4***Summary of Eren's Cultural Systems Literacy in Water Context*

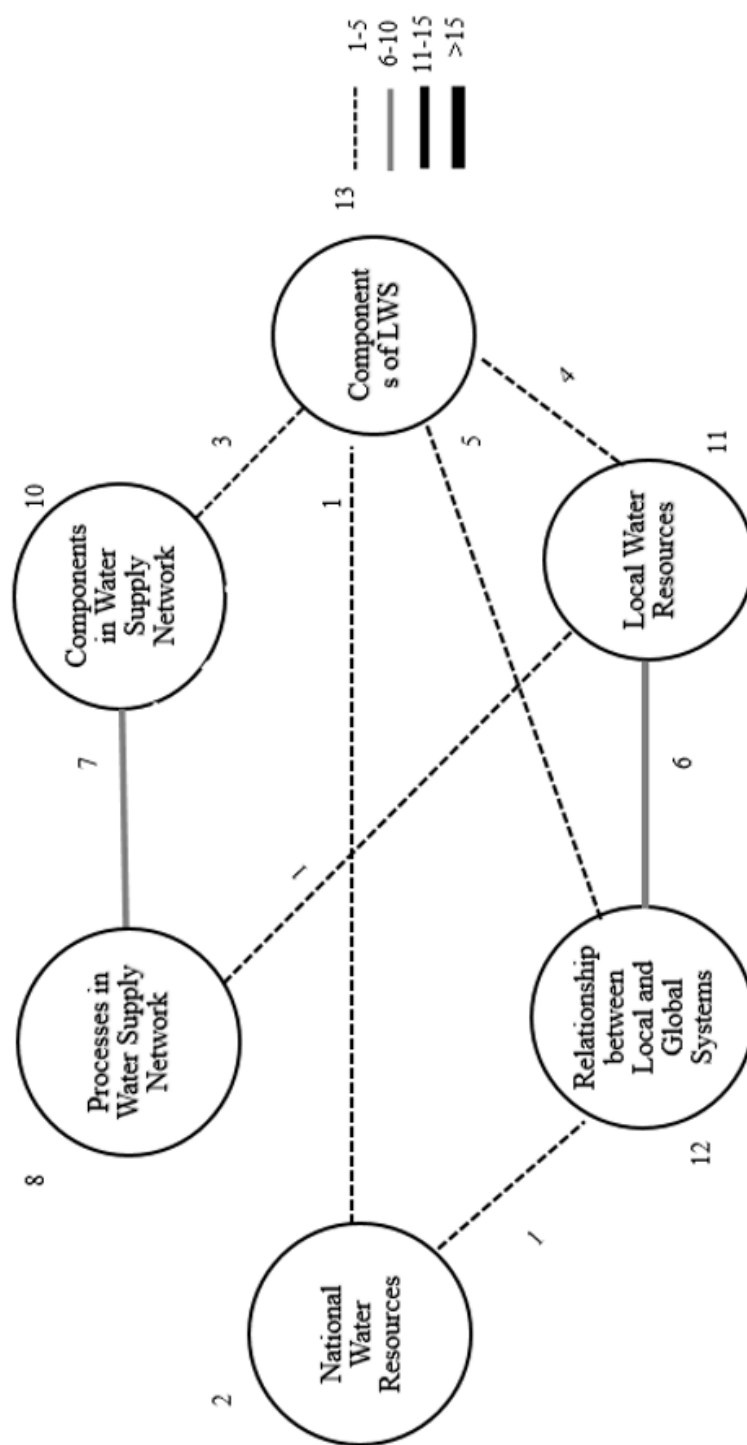
| Categories / Codes*                                  | Declarative<br>Procedural | Fully<br>Correct<br>Statement(s) | Partially<br>Correct<br>Statement | Incorrect  |              | Don't<br>Know |
|------------------------------------------------------|---------------------------|----------------------------------|-----------------------------------|------------|--------------|---------------|
|                                                      |                           |                                  |                                   | Consistent | Inconsistent |               |
| <b>Components of LWS</b>                             | Declarative               | ✓                                |                                   |            |              |               |
| <b>Local Water Resources</b>                         |                           |                                  |                                   |            |              |               |
| <b>Name of LWR</b>                                   | Declarative               |                                  | ✓                                 |            |              |               |
| <b>Functions of LWR**</b>                            | Declarative               |                                  | ✓                                 |            |              |               |
|                                                      | Procedural                |                                  | ✓                                 |            |              |               |
| <b>Water Supply Network and Sewerage System</b>      |                           |                                  |                                   |            |              |               |
| <b>Components</b>                                    | Declarative               |                                  | ✓                                 |            |              |               |
| <b>Processes</b>                                     |                           |                                  |                                   |            |              |               |
| <b>Water Accumulation</b>                            | Declarative               |                                  | ✓                                 |            | ✓            |               |
|                                                      | Procedural                |                                  | ✓                                 |            | ✓            |               |
| <b>Water Distribution</b>                            | Declarative               | ✓                                |                                   |            |              |               |
|                                                      | Procedural                |                                  | ✓                                 |            | ✓            |               |
| <b>Drinking Water Treatment***</b>                   | Declarative               |                                  |                                   |            |              | ✓             |
|                                                      | Procedural                |                                  |                                   |            |              | ✓             |
| <b>Wastewater Collection</b>                         | Declarative               | ✓                                |                                   |            |              |               |
|                                                      | Procedural                |                                  |                                   |            | ✓            |               |
| <b>Wastewater Treatment</b>                          | Declarative               |                                  |                                   |            | ✓            |               |
|                                                      | Procedural                |                                  |                                   |            |              | ✓             |
| <b>National Water Resources</b>                      |                           |                                  |                                   |            |              |               |
| <b>Water Resources Potential</b>                     | Declarative               | ✓                                |                                   |            |              |               |
| <b>Relationship between Local and Global Systems</b> |                           |                                  |                                   |            |              |               |
| <b>LWS - Hydrosphere</b>                             | Declarative               |                                  | ✓                                 |            |              |               |
|                                                      | Procedural                |                                  | ✓                                 |            | ✓            |               |
| <b>LWS - Biosphere</b>                               | Declarative               | ✓                                |                                   |            |              |               |
|                                                      | Procedural                |                                  | ✓                                 |            |              |               |
| <b>LWS - Anthroposphere</b>                          | Declarative               | ✓                                |                                   |            |              |               |
| <b>LWS-Geosphere</b>                                 | Declarative               | ✓                                |                                   |            |              |               |
| <b>TOTAL (n)</b>                                     |                           |                                  |                                   |            |              |               |
| <b>Declarative (D)</b>                               |                           | 7                                | 10                                | 0          | 6            | 3             |
| <b>Procedural (P)</b>                                |                           | (7D)                             | (5D, 5P)                          |            | (2D, 4P)     | (1D, 2P)      |

\* Not all categories/codes were given in this table since some of them were not observed in all participants

\*\* Even though participants have partially correct response in declarative knowledge, (s)he has fully correct response for the procedural knowledge.

\*\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception. OR they stated that they did not know the answer but tried to answer, though.

**Figure 5.8**  
*Mapping the Interactions among the Categories of Eren's Cultural Systems Literacy*



### **5.3.1.3 Eren's Critical Systems Literacy**

There are two themes in the cultural systems literacy as advance mechanisms in water system, and invisible elements of human system. The findings in this section will be given under these two themes as well as their categories. [Table 5-5](#) summarized the themes, categories, and codes of Eren's critical systems literacy in water context.

#### **5.3.1.3.1 Advance Mechanisms of Water System**

The theme of advance mechanisms of water system had following categories: dynamic nature of water system, causal dynamics and feedback loops, evolution of the system, and complexity of the water system. Each category was given in the subsequent sections.

##### **5.3.1.3.1.1 Dynamic Nature of Water System**

In his part of the interview, the questions were centered around the effects of unconscious use of water and its dynamic effects on the water system. As stated in the section of Quantity of Water, Eren was aware of that the total volume of the water is almost constant. Correspondingly, further questions were asked to portray his mental model on the unconscious use of water and its dynamic effect in the water system. Eren reflected his understanding on time delays in water system. The conversation was given below.

Interviewer: Eren, if the amount of water is constant, why are we concerning about the depletion of the water resources?

Eren: Because the water is polluted... Although the amount of water is constant, the proportion of drinkable water decreases since either people or the other living organisms pollute it... We couldn't use it because of this reason. The expenditure of treating the wastewater would be so high that it is not feasible. Governments wouldn't do that unless a risky situation emerges.

Interviewer: So, what happens to that polluted water?

Eren: Even though they evaporate and are purified at some point, the rate of evaporation changes since different substances increase its boiling point. In this way the amount of water in the water cycle decreases. In other words, the rate of cycling decreases.

**Table 5-5***Themes, Categories and Codes – Eren's Critical Literacy*

| Theme 1: Advance Mechanisms in Water System                         |                                         |                 |
|---------------------------------------------------------------------|-----------------------------------------|-----------------|
| Category 1.1: Dynamic Nature of Water System                        |                                         |                 |
| CRDN111: Time Delay                                                 | CRDN112: Redistribution of Water        |                 |
| Category 1.2: Causal Dynamics and Feedback Loops                    |                                         |                 |
| CRFL121: Simple Open Loop                                           | CRFL123: Balancing Loop                 |                 |
| CRFL122: Reinforcing Loop                                           | CRFL124: Open Loop with multiple causes |                 |
| Category 1.3: Evolution of Water System                             |                                         |                 |
| CREV131: Decaying                                                   | CREV133: Toward higher organization     |                 |
| CREV132: Steady state                                               |                                         |                 |
| Category 1.4: Complexity of Water System                            |                                         |                 |
| Sub-Category 1.4.1: Interruptions in the Water System               |                                         |                 |
| CRCO1411: Climate Change                                            | CRCO1412: Hidden Use of Water           |                 |
| Sub-Category 1.4.2: Layers of Complexities                          |                                         |                 |
| CRCO1421: Environmental                                             | CRCO1424: Health                        |                 |
| CRCO1422: Economic                                                  | CRCO1425: Educational                   |                 |
| CRCO1423: Social                                                    | CRCO1426: Governmental                  |                 |
| Theme 2: Invisible Elements of Human System                         |                                         |                 |
| Category 2.1: Beliefs on Water Use                                  |                                         |                 |
| CRBL211: Self-use of water                                          | CRBL213: Sources of Beliefs             |                 |
| CRBL212: Collective use of water                                    |                                         |                 |
| Category 2.2: Self-efficacy towards Efficient Water Use             |                                         |                 |
| CRSE221: High                                                       | CRSE222: Low                            |                 |
| Category 2.3: Motive Concern                                        |                                         |                 |
| CRMC231: Social Altruistic                                          | CRMC233: Biospheric                     |                 |
| CRMC232: Egoistic                                                   |                                         |                 |
| Category 2.4: Action Strategies for Efficient Water Use             |                                         |                 |
| CRAC241: Persuasion                                                 | CRAC244: Reuse of water                 |                 |
| CRAC242: Water loss prevention                                      | CRAC245: Recycle of water               |                 |
| CRAC243: Reduce of water use                                        | CRAC246: No action                      |                 |
| Category 2.5: Emotional response                                    |                                         |                 |
| CREM251: Anger                                                      | CREM253: Happiness                      | CREM255: Apathy |
| CREM252: Sadness                                                    | CREM254: Proud                          |                 |
| Category 2.6: Motivational Orientation for Sustainable Use of Water |                                         |                 |
| CRMO261: Intrinsic motivation                                       | Amotivation                             |                 |
| CRMO262: Extrinsic motivation                                       |                                         |                 |



The analysis of his responses revealed that Eren was aware on the time delays in the water system. He attributed time delays to the slower rate of evaporation. However, his reasoning, though including the correct scientific explanation, is partially correct and formed as *in situ*. As he did not know the wastewater treatment techniques, he thought that it is not feasible to do it. Moreover, he assumed that if a water resource has a slower rate of evaporation, the amount of water in the water cycle would be affected. He presumed that unless water evaporates, it could not be considered within the water cycle.

Eren mentioned redistribution of water in the water system when he was talking about the effects of people on the water system as following:

Interviewer: ... So, do people affect the water system? Why or why not?

Eren: They have both positive and negative effects. Water system also affects people ... *(the conversation continues)* ... One of their effects is global warming. Global warming leads to drought by slowing down the water cycle which prevents raining. This results in drought, at the end. While drought appears in some region, floods are experiences in another region.

... *(the conversation continues after the excerpt)* ...

Interviewer: How do people's negative effects influence the water cycle? Please elaborate your reasoning.

Eren: As I said earlier, it slows down the water cycle. They may change the rate of evaporation (*referring polluted water have different rate of evaporation than pure water*). Besides, they also intensify the water cycle which leads to an increase in the amount of precipitation... Conversely, when they slow down the water cycle, the amount of water in the water cycle decreases.

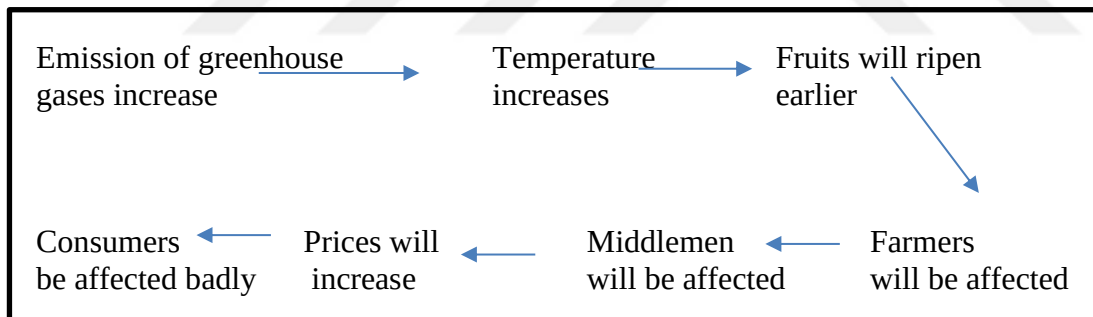
The analysis of his responses revealed that he explained redistribution of the water based on the effects of global warming. He emphasized that the effects of global warming influence redistribution pattern of the water in water system. Overall, the analysis of his responses indicated that he attributed the time delays and redistribution of water were water pollution and global warming. However, he had also some alternative explanations that "the amount of water in water cycle decreases sue to water pollution".

### 5.3.1.3.1.2 Causal Dynamics and Feedback Loops

Causal dynamics and feedback loops were traced in the interview responses. In this section, two different styles were used to present the findings. If the participant's response were given in another section, related page numbers were reminded, and visualization of the causality/feedback loop was reported. If it was not presented before, then related excerpt and visualization were given. Arrows in the visualizations represent cause-effect relationship (i.e. A causes B will be given as A→B). The analysis of Eren's responses emerged one simple open loop, one open loop with multiple causalities, and two reinforcing loops. Simple open loop was detected while Eren was talking about complexity of the water system. In this category, the visualization was given in [Figure 5.9](#). The figure revealed that several disruptions or failures in water system will eventually have negative effects on human life.

**Figure 5.9**

*Eren's Simple Open Loop*



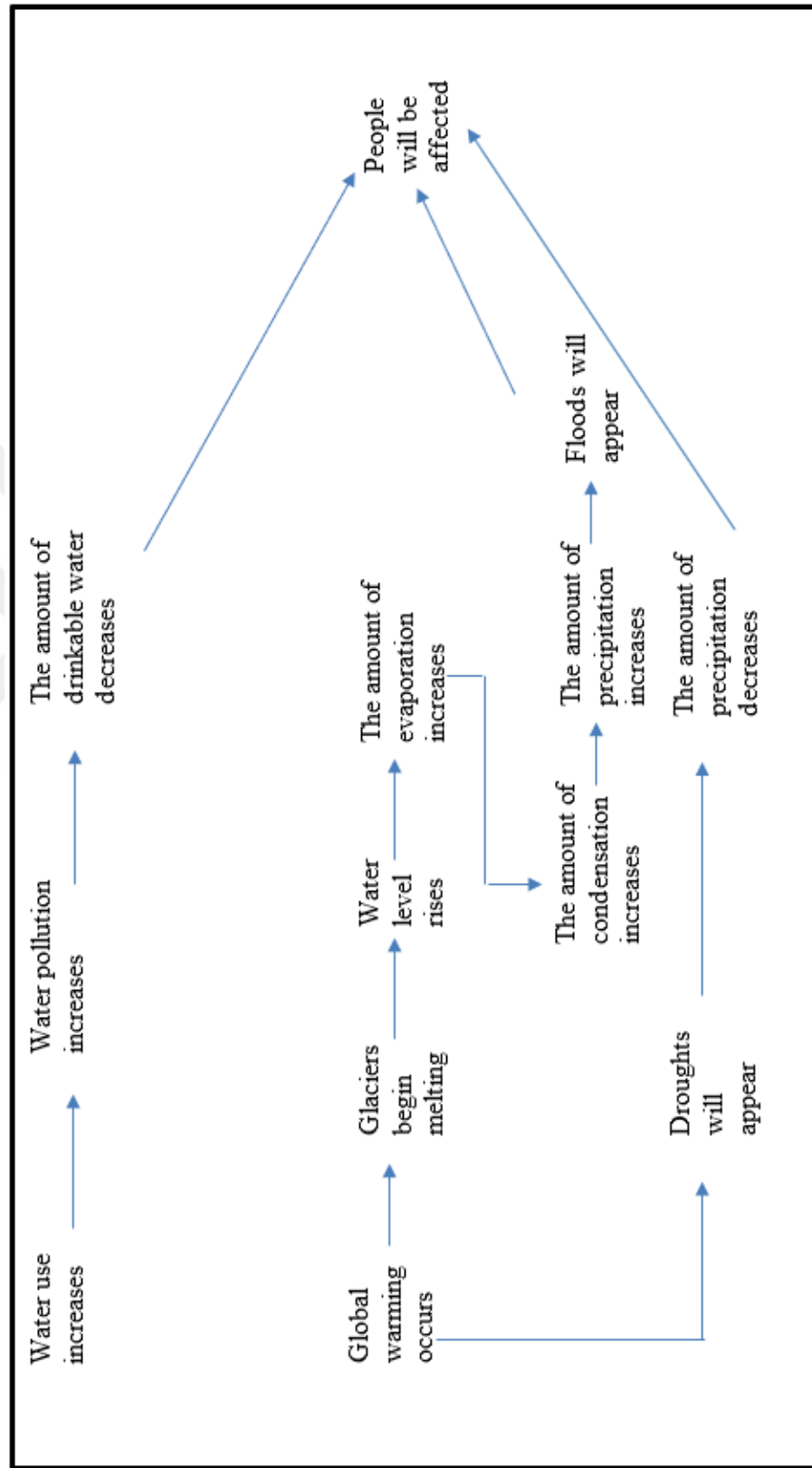
Open loop with multiple causes was observed in his responses related to the effects of the water system on people. Eren mentioned how people will be affected because of the several failures in the water system as following:

Global warming leads to glacier melting. This also result in water level rise. Consecutively, the amount of evaporation increases, so the amount of condensation. Therefore, the amount of precipitation increases. These events lead to floods and our life will be affected negatively.

Based on these sample excerpts, open loop with multiple causalities was visualized in [Figure 5.10](#).

**Figure 5.10**

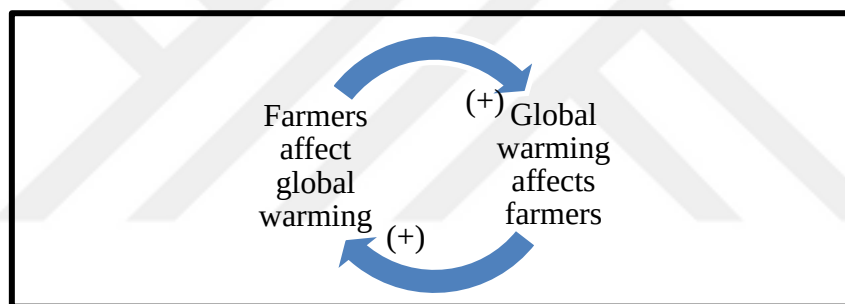
*Eren's Open Loop with Multiple Causalities*



In terms of feedback loops, Eren explained implicitly two simple reinforcing loops. While he was talking about the effects of global warming and a simulation about what happens when water cycle stops. His responses related to the effects of global warming was as following: “Farmers was affected due to the global warming. However, global warming is a man-made phenomenon. In other words, they are the ones who are responsible for the global warming due to their unconscious consumption habits” This sample excerpt can be visualized in [Figure 5.11](#). Note that that positive (+) signs indicates a change in one produces a change in another in the same direction.

**Figure 5.11**

*Eren’s Reinforcing Loop of Global Warming*



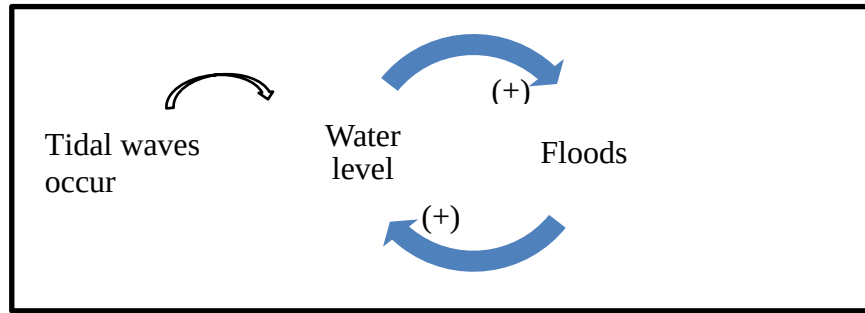
In another instance, while he was talking about a simulation about what happens when water cycle stops, he stated that:

Assume that no water cycles anymore and all the water remain in the liquid state on Earth. Sequentially, water level rises more than usual when tidal waves occur. This would lead to everlasting floods. These floods, in turn, intensify the sea level rise. This forms a vicious cycle.

This sample excerpt can be visualized below.

**Figure 5.12**

*Eren's Simple Reinforcing Loop of the Simulation*



Overall, Eren revealed his notion of causality in a system through the simple open loop, chain events in open loops and two reinforcing loops. While he was explaining his notion on the causalities, he mainly attributed these causalities to the effects global warming.

#### **5.3.1.3.1.3 Evolutionary Processes in Water System**

Evolutionary process in water system was examined in the interview phase 3 while I was asking participants about their predictions for the future scenarios of local, national, and global water system. Eren addressed possible evolutionary scenarios for his local water system and the global water system. Eren's response for evolutionary state of his local water system was following:

When we think about the present state of Ankara, we have not experienced any water-related problem yet. If the same conditions were conserved as it is and the consumption rate didn't change, I think that there will be no change between 20-50 years. It would be worse after that interval, if a drastic change occurred like being a big metropolitan i.e., Istanbul.

The analysis of the sample excerpt revealed that he predicted that the evolutionary state of his local water system as relatively constant since he presumed that no significant change would occur in the near future. In terms of global aspects, he stated that:

The amount of water in liquid state will increase globally; however, accessible water will decrease. In other words, they are inversely related to each other even if it does not sound logical. In the next 25 years, I expect no change. Media exaggerates sometimes to make something newsworthy. For example, if media announce that water scarcity begins, it may not reflect the case. Of course, the risk of water scarcity begins, but it takes years to face with water scarcity. I don't think we run out water in just 10 years. Maybe in the long run...

He claimed that there would be no change in the future of the global water system. His claim was based on his idea that it takes time to experience that kind of change. To sum up, the analysis of his responses revealed that he predicted no change in his local water system as well as the global water system in the coming years.

#### **5.3.1.3.1.4 Complexity of the Water System**

As Mobus and Kalton (2015) denoted, systems have different types and/or layers of complexity and these complexity and nonlinearities can be one of the sources of interruptions and failures in systems. Within the context of the water system, the issue of climate change and hidden use of water were included as two of the interruptions in the water system and possess many layers of complexity such as economic, social, environmental, educational, health, and governmental layers.

Participants' understanding on the issue of climate change was acquired based on a case which includes some hints about the layers of complexity in a narrative way. By using this case, it is aimed to explore students' understanding on the complexities in water systems. Correspondingly, a real story from Turkey was selected and interview phase 4 was constructed. For the hidden use of water, interview phase 3 were prepared to portray participants' notion on the hidden use of water.

#### *Climate Change and The Water System*

The analysis of this part revealed that Eren could be able to detect interruptions in the water system and some of the layers of its complexity in this story. I asked to him “*What happened to the water system in this story?*” His rationale was following:

Eren: At the beginning, man-made greenhouse effect leads to global warming. Drastic changes in the temperature creates an effect such that it is too hot at one day, while it is raining the other day.

Interviewer: Okay, thank you. So, it was written that the seasons began earlier than expected. What could be the reason for it?

Eren: Greenhouse gases accumulated in the atmosphere and this led to an increase in the amount of heat trapped in there. As a result, the average temperature in a season increases and trees are fooled by this hotness. Correspondingly, they start blooming earlier than they used to be.

Eren detected the failure of the water system within the case as climate change in an implicit manner. He explained the mechanisms of manmade greenhouse effect, global warming, and climate change, but he only failed to name it as climate change. In terms of layers of complexities, he mentioned the effects of climate change on the environmental, economic, social perspectives. A sample excerpt was given below.

Farmers were affected negatively; also, middlemen and consumers who possibly buy these products. Consumer wouldn't eat the products. Even if they could, the products would be too expensive... (*conversation continues*) ... And the plants, of course. As far as I remember, some crops should stay under the snow for a while to kill some bacteria. This is not going to happen because of global warming. Agriculture will be affected from this.

In short, Eren was able to identify the failure of the water system as climate change and explain its mechanism in detail based on the man-made greenhouse effect and global warming. Moreover, he identified three different layers of complexity as economic, social and environmental perspectives.

### *Hidden Use of Water and The Water System*

At this part, I asked some explicit questions to understand whether they are familiar this term or not. During the interview, if the interviewee has not ever heard about the term "hidden use of water", I tried to ask some triggering questions which are implicitly exploring interviewee's inferences on the concept of hidden use as well as perceptions on his/her water use. The reasons for asking these triggering questions is that (1) I presume that even though they may not be familiar the term "hidden use", they could be able to infer the concept; and (2) I want to reveal that whether

interviewees feel responsible or not, when they infer the consumption of water in a product that they buy.

When I asked Eren about the term “hidden use of water” during the interview, he said he has never heard this term before. Consecutively, I asked to him to think about whether there would be water consumption in foods that we eat or the clothes that we wear. A product, hamburger, that participants possibly consume was chosen as one of the concepts to enable them to think about the amount of water while manufacturing. I asked Eren to explain water consumption in a hamburger. He responded as following:

Interviewer: What about, for instance, a hamburger? Do we spend water for it?

Eren: Let’s think about the meatball in the hamburger. It comes from an animal. It drinks water to survive. Then, it is slaughtered, and its meat is cleaned. There is also a water consumption in here. On the other hand, potatoes also need water to be fried. Oil production also need water. If we think about the mills for the bread production, water is also consumed in there.

Interviewer: OK, when you think about all the process of hamburger production, who are responsible for the consumption of water?

Eren: There is something oddly happening in this situation. I think the person who buy this hamburger is the responsible of the all-water consumption. All the amount of water was spent for her/him so that (s)he could eat that hamburger.

The analysis of the conversation revealed that Eren had no declarative knowledge about the term “hidden use of water”. However, when more elaborative questions were asked about water consumption in a product, for example, he had the ability to infer the consumption of water at some level, but he failed to include the amount of the water for animals’ grain, vegetables in the hamburger and hamburger’s packaging process as well as wastewaters spent for the production. This indicated that he had procedural knowledge partially about the processes during the production. Besides, he stated that the consumers were responsible for the water consumption since (s)he bought it.

#### **5.3.1.3.2 Invisible Elements of Human System**

In this section, the findings were given within the categories of beliefs about water use, action strategies for efficient water use, emotional responses, motive concerns, and



motivational orientation for sustainable water use. The category of self-efficacy beliefs towards efficient water use was not emerged in Eren's responses.

#### **5.3.1.3.2.1 Beliefs on Water Use**

In this part, beliefs were summarized under the two sections as self-use of water and collective use of water. Beliefs on self-use of water covered the beliefs on both direct and hidden use of water from daily life. On the other hand, beliefs on collective use of water included beliefs on how other people use water in their daily life.

##### *Beliefs on Self-use of Water*

Self-use of water was traced in the interview part. The analysis of Eren's responses indicated that he had descriptive belief. The only belief that he shared during the interview that he did not waste the water most of the time which was classified as descriptive belief. This was summarized with his sources of his belief. To explore the sources of his descriptive belief, I asked to him in which activities does he consume water in a day. He stated that:

I use water in bathroom and the restroom. I also consume water after eating because there is also water consumption while they are cooking. Frankly, I use water in every hour a day because human being consume water in his/her daily life in every hour for doing or eating something... (*conversation continues*) ... I try not to waste it while I am using it. I hope I am not doing it.

Analysis of his responses revealed that he formed his descriptive beliefs based on daily experiences related to direct use of water. Since he did not know the concept of hidden use of water, which was given in the previous section, he failed to include his hidden use of water. In short, he had descriptive belief on his self-use of water. While he was mentioning it, he also gave his rationale from his direct experiences.

##### *Beliefs on Collective Use of Water*

In this part, the role of people in water system was asked to trace Eren's beliefs on collective use of water. In terms of the role of people in the water system, he had

inferential belief that *“The rate of wasting water is increasing in these days”*. He explained his inference as *“Wasting the water is increasing. For example, the school’s cafeteria is serving the foods more than we consume, so it goes to the trash. Even in this specific example is related to wasting the water because water is spent during the preparation process.”* In this excerpt, he observed foods are wasted in cafeteria and he inferred that this activity also led to water waste since water is consumed for preparing these foods.

Eren had also informational beliefs that people had (1) positive effects on the water system in terms of environmental aspect and (2) negative effects on the water system in terms of (a) environmental, (b) economic, and (c) social aspects. He formed these beliefs from the outside sources. He stated that as following:

People have both positive and negative effect on the water system. From the positive perspective, if there is a plant in an area but lack of water, people carry water to that plant. Plant and people together help to the water cycle by performing transpiration and photosynthesis. I know this is a biological concept, but water is released as a result of this transpiration. This makes a positive effect to the water system. On the other hand, even though there are some people using water consciously, there also some using water recklessly. This has negative effects on the environment as well as the economy. Accessible and drinkable water is decreasing day by day. Besides, people lead to glacier melts with the global warming. This affects the water system. Water level rise and tsunami and floods appear. These events have negative effects on people’s lives as well as their use of water and the water system. Droughts are emerged too.

The analysis of this sample excerpt as well as his other responses during the interview revealed that he formed inferential belief and informational beliefs for the collective use of water. His sources for these beliefs were reported by Eren in different instances on the interview such as inference from direct experiences, media, articles, and seminars that he attended.

#### **5.3.1.3.2.2 Action Strategies for Sustainable Water Use**

In this section, participants’ explicit statements about their action strategies for efficient or sustainable water use was given. As Eren reported that he participated in a seminar related to the context of sustainability, the interview was built based on his

action strategies of sustainability water use. Correspondingly, I asked him to explain whether he set a goal related to sustainable water use in his daily life. His response was following:

The only strategy that I have related to sustainable water use is to try not to waste water so that we, the humanity, could be able to use the water much longer. In this way, I also contribute to preventing the pollution of water. On the other hand, I am working on an energy efficiency project in my high school and it is indirectly related to saving water. The aim of our project is about improving heat storage systems and we get help from salty water to do this. Current thermal power plants lead to water pollution. In my project, this is not the case.

The sample excerpt revealed that his action strategies were related to his direct use. However, he did not give detail about in which activities he tried not to waste the water. Eren stated that the reason for not wasting water was the state of future generations. Additionally, he did not share any action strategies related to his hidden use of water because he already reported that he did not know the meaning of the term.

Eren also mentioned his project about energy efficiency in heat storage systems. He stated that this project was indirectly related to saving water and preventing water pollution in terms of his action strategies. Apart from these strategies, Eren also mentioned that about persuasion to other people about not wasting the water. He stated that *“I sometimes interfere with my sibling’s water consumption behavior, when (s)he consumes water much more it is needed.”* In short, prevention of water loss and persuasion were Eren’s self-reported action strategies to use water sustainably. He mentioned his action strategies by including future generations, energy-efficiency, and preventing water pollution which are related to some of the sustainable development goals. This will be discussed in the next chapter.

#### **5.3.1.3.2.3 Emotional Response**

His emotions related to effects of people on the water system were asked. He said he was angry about the negative effects of people on the water system. On the other hand, he stated that he was happy when he sees that some people water an arid region. The

analysis of his responses indicated that anger and happiness were the two emotional responses that he had related to the water system.

#### **5.3.1.3.2.4 Motive Concerns**

Motive concerns of the participants were examined by the interview questions. Correspondingly, the responses of the interview questions were analyzed to portray their motive concern. Eren revealed his motive concerns while he was talking about the importance of water system. The sample excerpt was given below.

It is important to maintain not only the water cycle but also the water system because all living organisms depend on water. Assume that no water cycles anymore and all the water remain in the liquid state on Earth. Sequentially, water level rises more than usual when tidal waves occur. This would lead to everlasting floods. These floods, in turn, intensify the sea level rise. This forms a vicious cycle. This could be dangerous for the living organisms. On the other hand, maintaining water supply network is also important since it makes human life better. We do not have to carry water from somewhere, there is an automatization for the circulation of water.

While Eren shared his ideas about maintenance of water system, he emphasized all living organisms, who are possibly be affected from disruption in the water system. This response was an indicator of his biospheric motive concern. In addition, he also emphasized the importance of water supply network for people's life. This was an indicator of social altruistic motive concern. During different instances in his interview, his social altruistic motive concern was dominant compared to biospheric motive concern. A sample excerpt was given below.

Interviewer: Why do you have specific goal orientation to use water efficiently?

Eren: So that we could live in the same conditions that we have now. In other words, in order not to face any difficulty or drought, I try to use water sustainably.

The analysis of his response revealed his social altruistic motive concern. He stated that he used water sustainably so that future generations would use it too. In short, Eren hold different motive concerns about the present state of water system, but social altruistic value orientation was dominant in his responses.

#### 5.3.1.3.2.5 Motivational Orientation

In terms of motivational aspect, it was asked to Eren that the sources of his motivation if any when he used water efficiently. His specific answer related to that question was following:

Even if I am not motivated all the time, there are some circumstances to motivate me to use water sustainably. For example, whenever I see that my brother wastes the water, I prevent him from doing it. On the other hand, I want to become a political leader when I grow up. This motivates me as if I am already a politician. Actually, the feeling of doing the right thing motivates me.

The analysis of his responses indicated that he had *extrinsic motivation*. Extrinsic motivation refers to a construct "...that pertains whenever an activity is done in order to attain some separable outcome." (Ryan & Deci, 2000, p.60). In his case, Eren used water efficiently since doing the right thing motivated him. The compatibility of the behavior with his future career choice provided a basis for his actions.

#### 5.3.1.3.3 Summary of Eren's Critical Systems Literacy in Water Context

The analysis of Eren's critical systems literacy in water context were given in two themes. In terms of advance mechanisms of water system, Eren's explanations were categorized in four categories. In term of dynamic nature of water system, Eren reflected his notion on time delays and redistribution of water in water system. He partially explained about how these dynamical mismatches occur. On the other hand, he exemplified causal dynamics by explaining them as simple open loop, two open loops with multiple causalities, and two simple reinforcing loops. While he was explaining his notion on the causalities, he mainly attributed these causalities to the effects global warming. In terms of evolutionary processes in the system, the analysis of his responses revealed that he predicted no change in his local water system as well as the global water system in the coming years. Last, Eren's reflections related to the real story and the concept of hidden use of water were indicators of his notion on the complexity of the water system. He detected climate change as a disruption in the water system and he mentioned three different layers of complexity as economic,

social and environmental perspectives. In terms of hidden use of water, however, he had no declarative knowledge, but was able to infer some of the processes during the manufacturing of the products. Besides, he specified that the consumers were responsible for the water consumption since they bought it.

Under the theme of invisible elements of human system, Eren's responses were given by means of five categories. In terms of beliefs on water use, he reflected his beliefs on self-use and collective use of water. He gave detailed information about the sources of his beliefs. He had descriptive on his self-use of water as "*I do not waste the water most of the time*". While he was mentioning it, he also gave his rationale from his direct experiences. In terms of the role of people in the water system, he had descriptive belief that "The rate of wasting water is increasing in these days"; informational beliefs that people had (1) positive effects on the water system in terms of environmental aspect and (2) negative effects on the water system in terms of (a) environmental, (b) economic, and (c) social aspects. He formed these beliefs from outside sources as direct experiences, media, articles, and seminars that he attended. Action strategies of Eren for sustainable water use were related to his direct use. However, he did not elaborate in which activities he tried not to waste the water. Additionally, he did not share any action strategies related to his hidden use of water since he did not know the meaning of the term. Anger and happiness were the two emotional responses that he had related to the water system. Social altruistic and biospheric value orientations were observed and social altruistic was dominant motive concern. Last, he attributed his motivation about sustainable use of water to his future career choice; thus, he had extrinsic motivation.

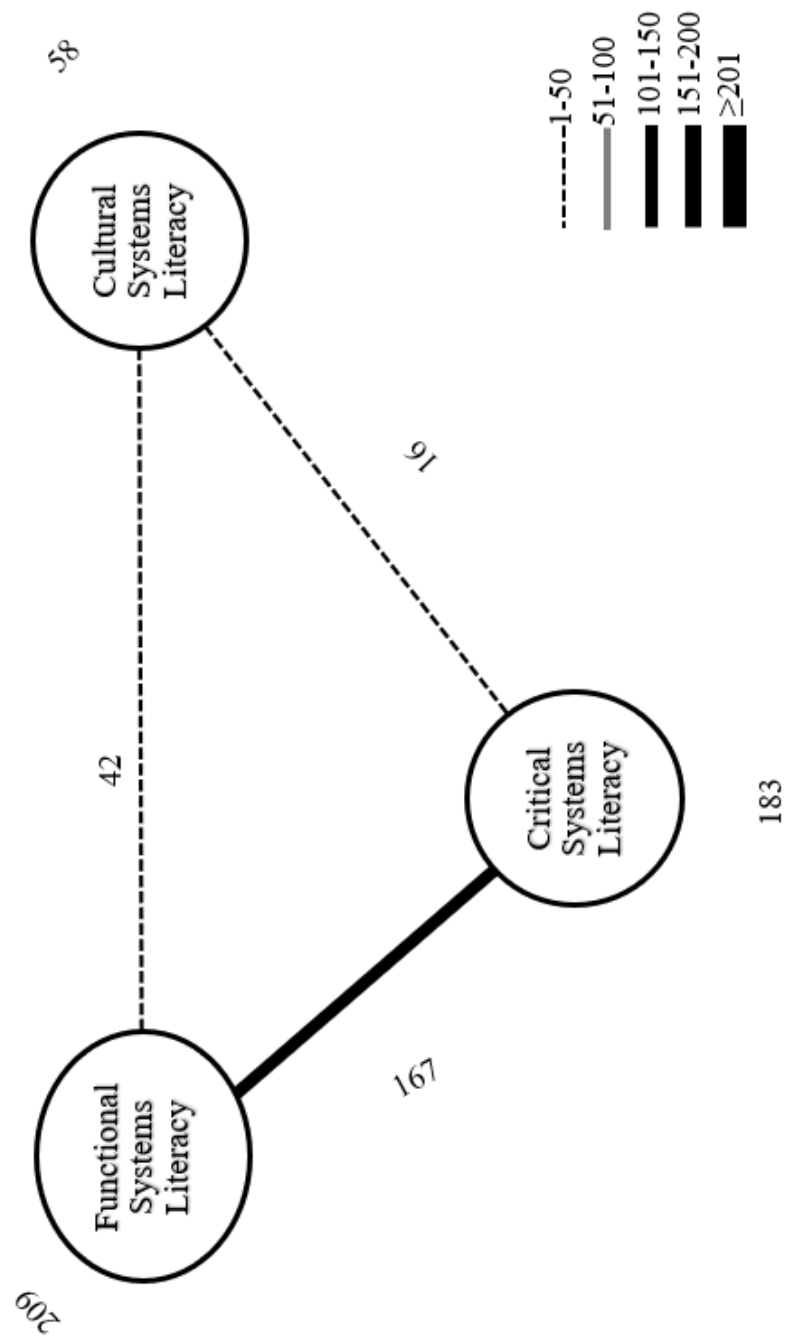
#### **5.3.1.4 Mapping the Interactions of the Categories in Systems Literacy**

To explore the interactions among the FSL, CUSL, and CRSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.22](#) revealed the map. The order of the interactions from highest to the lowest among the elements of systems literacy was FSL-CRSL, FSL-

CUSL, and CUSL-CRSL. The interactions among the elements of systems literacy of Eren in terms of water system can be summarized based on the content analysis of this section as following:

- Eren had substantial amount of knowledge about the basic mechanisms of water system (FSL) compared to basics of his local water system (CUSL).
- revealed that *Critical Systems Literacy* was interactive literacy element among the others, whereas *Cultural Systems Literacy* was least interactive.
- The number of interactions between *Functional Systems Literacy* and *Critical Systems Literacy* were higher than the other combinations of interactions (CUSL-CRSL; FSL - CUSL).

**Figure 5.13**  
*Mapping the Interactions among Eren 's Systems Literacy Elements in Water Context*





### 5.3.2 Case 2: Cansu

Cansu was born in 2003. She is a ninth-grader female student in a social sciences public high school located in an inland city. Her school runs a two-semester English Language Preparatory Program for the students before pursuing their high school program. It is one of the high schools that accept students according to their national entrance exam scores. Cansu's entrance exam score was 421 out of 500 points which corresponds to top 18% of the applicants in that year. She enrolled the preparatory program twice since she failed to pass the preparatory class in the first year.

Cansu's parents used to be farmers. Currently, her mother is a cook in a local diner; her father is a worker. Still, they are farming for themselves and for their animals. Farming is one of the main jobs in her village, though. Besides, Cansu's family has also some animals in their garden. They sell neither the animals nor their dairy products. They only provide their nutrients from the animals. Their village is in a riverside. Although Cansu is staying in dormitory during the semesters, she visits her childhood residence in semester breaks as well as in holidays.

In her middle school years, she enrolled two projects related to water pollution and water shortage problem. Both their village and her school are near River Kızılırmak, her teachers arranged an event "garbage collection" from the river. Students collected garbage from the surface of River Kızılırmak. The second project was using well waters as a water resource since there was water shortage problem in her village during summers. They prepared a project proposal and presented to Mayor. Then, their projects put into practice by the municipality. Besides, her high school offers a course "Social Activities" aimed to increase awareness of the students in (1) social sensitivity; (2) nature and environment; and (3) culture and art. Her teacher in this course was interested in water-related issues and included these issues into her classes. Different presentations, guest speakers, and documentaries were integrated into the lectures correlated with the aim of the course.

Cansu reported that she did not remember the context of sustainability. In the ninth grade before I collected data from her, properties of water as a universal solvent and water as a polar molecule were taught in her chemistry class. On the other hand, water was also included in geography class as hydrosphere within the context of Earth's spheres.

I worked with Cansu in two sessions. The responses of Cansu through the conception test, first drawing task, and interview questions reflected some indicators related her systems literacy. The analyses of her responses were given below under the elements of functional systems literacy, critical systems literacy, and cultural systems literacy.

#### **5.3.2.1 Cansu's Functional Systems Literacy**

The analysis of Cansu's responses in conception test, first drawing task and interview phase 1 revealed her functional systems literacy in five categories as (1) general characteristics of water; (2) power sources of water cycle; (3) components of water cycle; (4) processes of water cycle and (5) relationship between the Earth systems. [Table 5-6](#) indicated codes and categories for her functional systems literacy in water context.

##### **5.3.2.1.1 General Characteristics of Water**

The first category in explaining Cansu's functional systems literacy was general characteristics of water. Cansu's answers for the questions for this session were given by means of quantity of water, its cyclic nature, relational responsiveness, and water in living organisms.

##### ***Quantity of Water***

Quantity of water refers to (1) compare the proportions of water stored in different water resources (2) state that almost all the amount of water does not change on Earth. In conception test, Cansu correctly responded that most of the water on Earth is found in oceans. On the other hand, she revealed her misconception that "*the amount of water on Earth decreases*" with the confidence rating of "*I am sure*". (please see )

**Table 5-6***Themes, Categories and Codes of Cansu's Functional Systems Literacy*

| <b>Theme - Basics of Water System</b>                         |                                     |
|---------------------------------------------------------------|-------------------------------------|
| <i>Category 1: General Characteristics of Water</i>           |                                     |
| FGC11: Quantity of Water *                                    | FGC14: Water and Living Organisms   |
| FGC12: Cyclic Nature                                          | FGC15: Relational Responsiveness    |
| FGC13: Properties of Water**                                  |                                     |
| <i>Category 2: Power Sources of Water Cycle</i>               |                                     |
| FPS21: Sun                                                    | FPS23: Gravity                      |
| FPS22: Wind                                                   |                                     |
| <i>Category 3: Components of Water System</i>                 |                                     |
| FC31: Plant                                                   | FC317: Cloud                        |
| FC32: Sun                                                     | FC318: Rain                         |
| FC33: Water                                                   | FC319: Snow                         |
| FC34: Animal                                                  | FC320: Fog                          |
| FC35: Human                                                   | FC321: Hail                         |
| FC36: Ocean                                                   | FC322: Freshwater                   |
| FC37: Sea                                                     | FC323: Ice                          |
| FC38: Water Vapor                                             | FC324: Well                         |
| FC39: River                                                   | FC325: Lake                         |
| FC310: Glacier                                                | FC326: Stream                       |
| FC311: Spring                                                 | FC327: Dew                          |
| FC312: Soil                                                   | FC328: Algae                        |
| FC313: Wetland                                                | FC329: Creek                        |
| FC314: Rock                                                   | FC330: Puddle                       |
| FC315: Groundwater                                            | FC331: Mountain                     |
| FC316: Aquifer                                                |                                     |
| <i>Category 4: Processes of Water System</i>                  |                                     |
| FP41: Evaporation                                             | FP410: Surface flow                 |
| FP42: Condensation                                            | FP411: Melting                      |
| FP43: Sublimation                                             | FP412: Freezing                     |
| FP44: Evapotranspiration                                      | FP413: Frosting                     |
| FP45: Respiration                                             | FP414: Dissolution                  |
| FP46: Precipitation                                           | FP415: Transpiration                |
| FP47: Penetration                                             | FP416: Capillarity                  |
| FP48: Infiltration                                            | FP417: Photosynthesis               |
| FP49: Underground flow                                        |                                     |
| <i>Category 5: Interactions among the Earth (Sub)Systems*</i> |                                     |
| FRES51: Hydrosphere—atmosphere                                | FRES55: Hydrosphere-anthroposphere  |
| FRES52: Hydrosphere—geosphere                                 | FRES56: Water cycle- nitrogen cycle |
| FRES53: Hydrosph. (continental)—hydrosph. (marine)            | FRES57: Water cycle- oxygen cycle   |
| FRES54: Hydrosphere—biosphere                                 | FRES58: Water cycle – carbon cycle  |

\*black codes: emerged from Cansu's responses

\*\*pale codes: not apparent in Cansu's responses

In her interview, she elaborated the decrease in the total amount of water on Earth in different contexts as following:

As there is no recycling for water which penetrates the soil and leaks to the groundwater, the total amount of water decreases. For example, some of our wastewater in our village goes into the soil and it would not be usable anymore. I think this situation affects all the world since it leads to a decrease in the total amount of water on Earth.

*... (the conversation continues after the excerpt) ...*

The analysis of her answers in different forms of questions (conception test items, interview questions) indicated that she identified the highest proportion stored in the oceans. Moreover, she failed to express that the amount of water is almost constant on Earth. Instead, Cansu had a misconception and it was consistent and stable in different context during data collection.

### ***Cyclic Nature***

For obtaining information about her notion on the cyclic nature of water, the first drawing task, conception test, and interview questions was analyzed. In her drawing, she used arrows to show how water cycles. She indicated that water precipitates into a water resource and then, the water goes back into atmosphere thanks to the evaporation. Additionally, she added groundwater inside a mountain, and it has no connection with the water cycle. The figure was given in [Figure 5.14](#).

After the first drawing task ended, she explained how water cycle occurs as following:

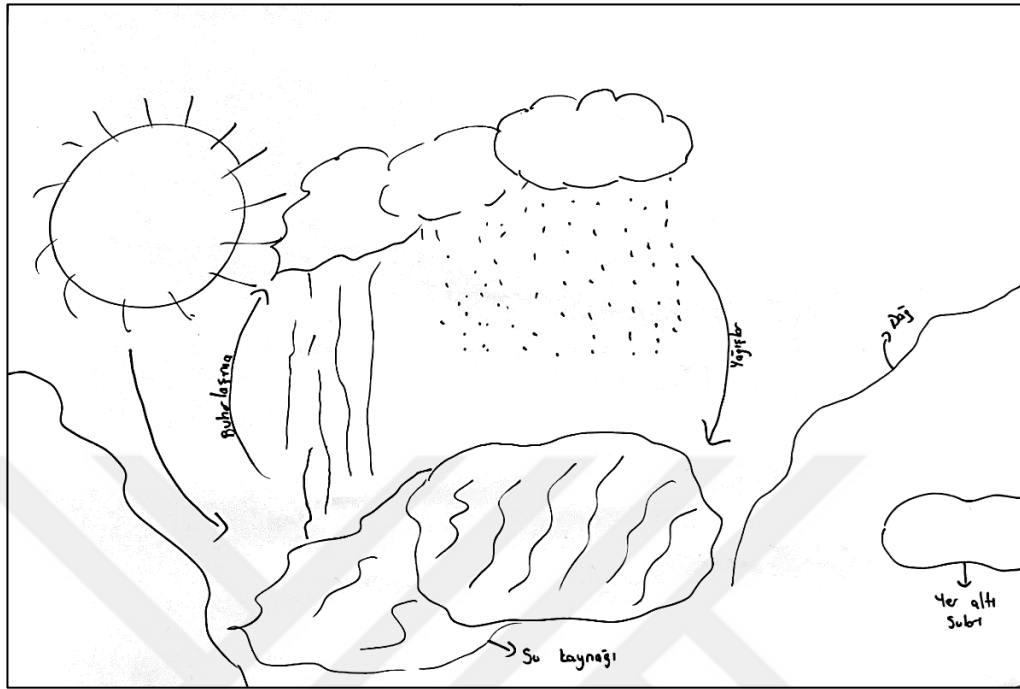
Cansu: At first, it's raining and collecting in lakes, rivers, and wetlands. Then, water evaporates with the help of the sun and goes into the clouds, that's all...

Interviewer: Okay. So, is there any starting or ending point?

Cansu: No because it always cycles, and it never stops. Hence, there is no starting or ending point. I learned this in social activities course offered by our high school.

**Figure 5.14**

*Cansu's Drawing of Water Cycle*



Analyzing of both her drawing and explanation revealed that she explained partially correct the cyclic nature of the water since she failed to indicate the evaporation from the land. Her responses indicated that water only evaporates from the water resources. Additionally, groundwater had no connection with the water cycle in her figure. In other words, the journey of water has ended deep in the mountain. She explained that *“It is so deep that we couldn’t reach the groundwater. Therefore, we couldn’t use groundwater”*. In a consistent manner, while we were talking about “where does water go when we discharge it?” she stated that *“The water that we use in our kitchen and bathroom goes directly the garden in my village’s house via pipes. You can see the wastewater flowing outside the house. There is no turning back for this water since it penetrates the soil and blends in the groundwater.”* Her drawing as well as this sample excerpt revealed that she had difficulties to imagine the connection between the groundwater and the water cycle. Besides, Cansu indicated that there is no starting/ending point of the water in the conception test (please see ).

All these forms of responses indicated that she had declarative knowledge on the cyclic nature of the water. She stated that she learned it in her school. On the other hand, she thought that groundwater does not take part in water cycle and this was an indicator for her lack of procedural knowledge on the cycling mechanism of water. She exemplified how domestic wastewater cannot take part in water cycle based on her daily life experience in her hometown. This misinterpretation was another indicator of her partial procedural knowledge on water cycles in different contexts.

### ***Relational Responsiveness***

Cansu was one of the participants to explain relational responsiveness of the water system within the context of living subsystem's reactions. She explained how local people in her village react when their water supply had been cut off in summers. The conversation was given below.

Interviewer: ... Does water system react when a problem occurs? Why or why not?

Cansu: As I said earlier, our water supply has been cut off in summers due to overuse of water. People carry water from somewhere else, mostly from the main county town, forty minutes' drive from the village. They either carry this water by car or use public transport. On the other hand, there is a spring water coming from the mountain which has never been cut off so far. My dad sometimes carry water to our home from the spring. This resource is fifteen minutes' drive from the village... (*conversation continues*) ... Carrying water does not enough to provide our daily needs. We have severe difficulties in cleaning such as take a bath, washing our hands or dishes. We only use it for drinking and cooking purposes.

Interviewer: So, what is the reaction of the people in your village for this problem?

Cansu: They get used to it. They never attempt to change their water consumption behavior.

The analysis of her responses revealed that she failed to reveal her declarative knowledge on the relational responsiveness of the systems in water context. However, she explained how a complex organization react to an event with a specific example from her village. Hence, the analysis of her response revealed that she reflected her partial procedural knowledge on the relational responsiveness based on her daily life experience.

## ***Water and Living Organisms***

Cansu explained the role of living organisms in the water system as well as their use of water for different purposes. She explained some interactions between the water and the living organisms, which are namely animal, and specifically, humanity. For example, she mentioned the amount of water in living organisms as “*97% of our body includes water.*” The statement revealed that she had declarative knowledge that we have substantial amount of water in our body, but the percentage that she gave was wrong.

In terms of humanity, she explained the positive and negative effects of human use of water on the water system. Overall, she had declarative knowledge on the interactions between the water and the living organisms. In terms of procedural knowledge, she only elaborated human use of water which will be given in the subsequent sections. She did not include processes in water system related to the other living organisms.

### **5.3.2.1.2 Power Sources of Water Cycle**

Cansu stated all the three power sources in different data sources. In her drawing, she included sun as a power source. On the other hand, she mentioned sun and wind during her interview. She only explained the role of sun as “*...Evaporation occurs because of the sun...*” she failed to explain the function of the wind as a power source. In conception test, Cansu responded correctly all three questions related to the power sources. ((please see ). To sum up, she correctly responded all three questions in conception test. However, she mentioned them in different forms of data source. Still, the data revealed that she stated sun, wind, and gravity as the power sources but partially revealed her procedural knowledge.

### **5.3.2.1.3 Components and Processes in Water System**

Within the context of the components of water system, Cansu mentioned 18 of 31 components in the conception test, her drawings as well as during the interview. In the conception test, she identified ocean as the biggest sources of water on Earth. In her drawing (Figure 5.14), she used the components such as water, sun, clouds, rain, and groundwater. On the other hand, she mentioned animals, human beings, plants, soil,

wetland, puddle, glacier, sea, mountain, spring, well, and river during the interview in different occasions.

In terms of processes, she identified four processes of out 17. In her drawing (Figure 5.14), she indicated the processes of evaporation and precipitation. On the other hand, she mentioned penetration and melting during the interview. While she was talking about these two processes, she revealed some misconceptions. For penetration, she stated that *“Water penetrates to soil and it will be no longer used by human. Correspondingly, the total amount of water decreases on Earth”*. For melting, she explained her rationale as *“Hole in the ozone layer leads to glacier melting. The weather would be hotter because of the that hole. Then, glaciers start to melt and result in climate change.”* Even though she explained correctly the mechanism of melting in terms of heat exchange, she misinterpreted the phenomenon of glacier melt.

During the data collection, Cansu reflected different components and processes. For example, she did not include all the processes and components that she identified in the conception test within her drawing. In her interview, she exemplified other components and processes. Overall, she exemplified 17 components of water system during the interview. Additionally, she named four processes of water system. While explaining melting and penetration, she revealed her misconceptions.

#### **5.3.2.1.4 Interactions among the Earth Systems**

The analysis of Cansu’s responses emerged four different relationships among the Earth systems as (1) hydrosphere and atmosphere; (2) hydrosphere and anthroposphere; (3) hydrosphere and geosphere; and (4) hydrosphere and biosphere. Besides these categories, she also mentioned some of them through three or more different combinations. Each code and their combinations were given below.

The analysis of his drawing, interview, and responses of the conception test had some indicators about her notion about the relationships between hydrosphere and atmosphere by indicating evaporation, clouds and precipitation in her drawing. On the other hand, she did not give detail about the mechanisms of precipitation. In terms of cloud formation, Cansu explicitly stated that she did not know how clouds form.



Similar with her explanation related to cloud formation, she had vague responses for the clouds in the conception test ((please see ). For the first question she chose the correct response that *“water vapor and dusts in the atmosphere are required for the cloud formation”* but with a wrong alternative and she was not sure about the answers which indicated lack of knowledge. For the other question, she selected the correct answer. In short, she was able to reveal partially her procedural knowledge on how clouds form by choosing the correct alternative but being not sure. Nonetheless, she failed to explain its processes during the interview.

When I asked, *“Is there any other system hidden in your drawing that might have an interaction with the water system?”* she emphasized hydrosphere-anthroposphere as following: *“I think water cycle affects people. If water cycle stops, then people will be in a bad situation. In contrast, people do not affect the water cycle.”* This sample excerpt revealed that she failed to state the dual interaction between the hydrosphere and anthroposphere.

The relationship between hydrosphere and geosphere emerged from the analysis of the interview. She mentioned this interaction in two instances. First, she stated that some of the water penetrates to the soil and leaks to the groundwater resources. This phenomenon results in a decrease in the total amount of the water. On the other hand, she mentioned a well near the agricultural area in her village. She explained that water pumped from the well was used for irrigational purposes. These two examples revealed her declarative knowledge on the interaction between hydrosphere and geosphere. However, she had a misconception on what happens to water after penetrates to the soil. The relationship among atmosphere, hydrosphere, and biosphere were given through two examples. First, she stated that *“Living organisms use water for survival purposes. For instance, animals use water either to drink it or clean themselves.”* In the latter part of her interview, she mentioned that *“When there are a lot of trees in an area, the rate of precipitation increases. It is good because our water potential increases.”* Overall, she revealed only her declarative knowledge on this interaction.

In brief, when we examine [Figure 5.14](#) as well as her responses in different data collection instruments, we can summarize her functional systems literacy in [Table 5-7](#).

This table reviewed her knowledge not only in terms of level of correctness but also labeled that specific knowledge as declarative or procedural. Additionally, table also elaborated the incorrect responses as either it is a consistent and stable or it was produced *in-situ* which is inconsistent and unstable.

#### **5.3.2.1.5 Mapping the Interactions of the Categories in Cansu's Functional Systems Literacy**

To explore the interactions among the categories in FSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.15](#) revealed the map was given below. The details of the mapping were given under the methodology chapter.

Based on the content analysis of this section, I can summarize Cansu's functional systems literacy in water context as following:

- [Table 5-7](#) revealed that Cansu have mostly declarative knowledge on the basic mechanisms of the water system.
- In terms of procedural knowledge, she had very limited understanding on the working principles of the water system.
- At some points while examining the procedural knowledge, some misconceptions were detected. [Figure 5.15](#)

- revealed that *Components of Water System* and *Processes in Water System* had most interactive categories among the others. In other words, while Cansu was talking about the basics of water system, she mostly used processes and components of the water system.
- *Power Sources of the Water Cycle*, on the other hand, was the most limited category among the others. There a limited number of integrations of the power sources into the other categories of FSL to explain the basics of the water system.

In the next section, Cansu's cultural systems literacy in water context will be given.

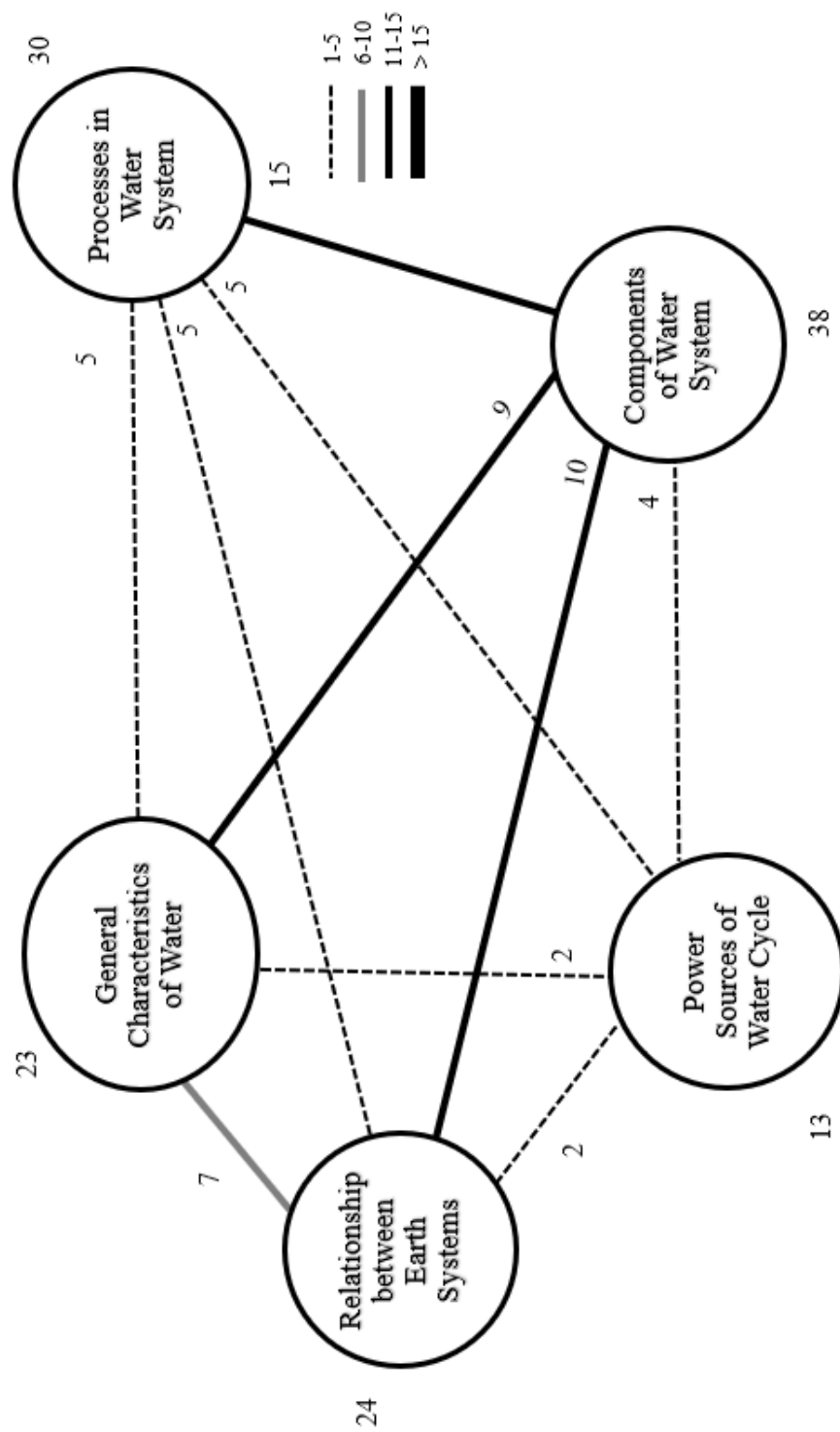
**Table 5-7**

*Summary of Cansu's Functional Systems Literacy in Water Context*

| Categories / Codes*                                | Declarative /<br>Procedural | Fully Correct Statement(s) | Partially Correct<br>Statement(s) |                  | Incorrect<br>Statement(s) |  |
|----------------------------------------------------|-----------------------------|----------------------------|-----------------------------------|------------------|---------------------------|--|
|                                                    |                             |                            | Consistent                        | Inconsistent     |                           |  |
| General Characteristics of Water                   |                             |                            |                                   |                  |                           |  |
| Quantity of Water                                  |                             |                            |                                   |                  |                           |  |
| 1. Proportion of water resources                   | Declarative                 | ✓                          |                                   |                  |                           |  |
| 2. Change in amount of water on Earth              | Procedural                  |                            |                                   |                  | ✓                         |  |
| Cyclic nature**                                    | Declarative                 | ✓                          |                                   |                  |                           |  |
|                                                    | Procedural                  |                            | ✓                                 |                  | ✓                         |  |
| Water and Living Organisms                         | Declarative                 | ✓                          |                                   |                  |                           |  |
|                                                    | Procedural                  |                            |                                   | ✓                |                           |  |
| Relational Responsiveness                          | Procedural                  |                            | ✓                                 |                  |                           |  |
|                                                    | Declarative                 | ✓                          |                                   |                  |                           |  |
| Power Sources of Water Cycle                       | Procedural                  |                            | ✓                                 |                  |                           |  |
|                                                    | Declarative                 |                            |                                   | ✓                |                           |  |
| Components of the Water System (17 out of 31)      |                             |                            |                                   | ✓                |                           |  |
| Processes of the Water System (4 out of 17)        |                             |                            |                                   | ✓                |                           |  |
|                                                    |                             |                            |                                   | ✓                | ✓                         |  |
| Relationship between the Earth System (4 out of 8) |                             |                            |                                   |                  |                           |  |
| Hydrosphere – Atmosphere                           | Declarative                 |                            |                                   | ✓                |                           |  |
|                                                    | Procedural                  |                            |                                   |                  | ✓                         |  |
| Hydrosphere – Biosphere                            | Declarative                 | ✓                          |                                   |                  |                           |  |
|                                                    | Declarative                 |                            |                                   | ✓                |                           |  |
| Hydrosphere – Anthroposphere                       | Procedural                  |                            |                                   | ✓                |                           |  |
|                                                    | Declarative                 | ✓                          |                                   |                  |                           |  |
| Hydrosphere – Geosphere                            | Procedural                  |                            |                                   | ✓                | ✓                         |  |
|                                                    | Declarative                 |                            | 6<br>(6 D)                        | 12<br>(4 D, 8 P) | 4<br>(4 P)                |  |
| TOTAL (n)                                          |                             |                            |                                   |                  | 0                         |  |
| (D: Declarative, P: Procedural)                    |                             |                            |                                   |                  |                           |  |

(D: Declarative, P: Procedural)  
 \*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception.

**Figure 5.15**  
*Mapping the Interactions Among the Categories of Cansu's Functional Systems Literacy*



### **5.3.2.2 Cansu's Cultural Systems Literacy**

Cultural systems literacy of Cansu traced through the second drawing task and phase 2 interview questions on CUSL. Her responses related to the basics of LWS was examined. [Table 5-8](#) indicated the categories and codes of Cansu's cultural systems literacy in water context.

#### **5.3.2.2.1 Components of Local Water System**

Even though her drawing was dominated by domestic water use, some other minor components were also drawn like agricultural areas. Her notion related to the other components of water system were traced through the interview questions. Her second drawing was given in [Figure 5.16](#).

Her drawing included a local water resource (LWR), an agricultural area with a well to irrigate crops, trees in her garden, water supply network and sewerage system items which can be considered as four of the components of her local water system. The subcategory of WSN and sewerage system will be variegated in the next section. During the interview, she also mentioned animals and human beings as components of LWS. She stated that her family and the other local people had livestock in their garden. She mentioned that these animals in her village also one of the components of her local water system since they use water for drinking and cleaning purposes.

#### ***Local Water Resources***

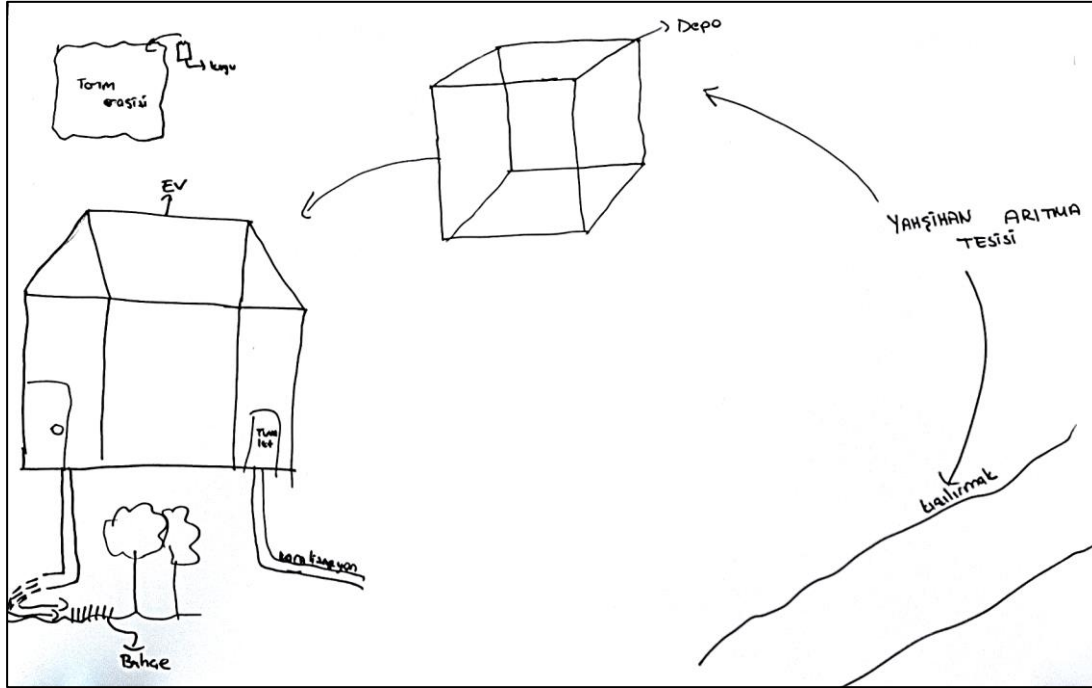
In terms of specific names and functions of LWR, Cansu mentioned that water demand in her village was mostly provided by the River Kızılırmak. She also mentioned two additional LWRs. She stated that a well was located near agricultural area and its water was used only for irrigational purposes and not suitable to drink. She reported that there are fountains around the village and sometimes people carried water of these fountains to their when water supply was cut off. She stated that the water of these fountains was coming from deep in the mountains. In terms of the functions of LWR, she explained that LWR were used for domestic, agricultural, and survival purposes.

**Table 5-8***Categories and Codes – Cansu's Cultural Literacy*

| Theme: Basics of Local Water System (LWS)                               |                |                       |                                |                      |  |
|-------------------------------------------------------------------------|----------------|-----------------------|--------------------------------|----------------------|--|
| Category 1: Components of LWS                                           |                |                       |                                |                      |  |
| Animal                                                                  | Human being    | Local Water Resources | Sewerage System                |                      |  |
| Plant                                                                   | Microorganisms | Water Supply Network  |                                |                      |  |
| Sub-Category 1.1: Local Water Resources                                 |                |                       |                                |                      |  |
| Sub-Category 1.1.1: Name of LWR                                         |                |                       |                                |                      |  |
| Lake Tuz                                                                | Lake Eymir     | Çubuk Dam             | River Kızılırmak               |                      |  |
| Lake Mogan                                                              | Kurtboğazi Dam | Aegean Sea            |                                |                      |  |
| Sub-Category 1.1.2: Functions of LWR                                    |                |                       |                                |                      |  |
| Survival                                                                | Recreational   | Energy source         | Industrial                     |                      |  |
| Domestic                                                                | Economical     | Religious             | Agricultural                   |                      |  |
| Sub-Category 1.2: Water Supply Network (WSN)                            |                |                       |                                |                      |  |
| Sub-Category 1.2.1: Components in WSN                                   |                |                       |                                |                      |  |
| River                                                                   | Hail           | Pipe                  | Drinking Water Treatment Plant |                      |  |
| Cloud                                                                   | Water Puddle   | Engineers             | Water Storage Facilities       |                      |  |
| Freshwater                                                              | Well           | Water ATM             | Fountain                       |                      |  |
| Rain                                                                    | Dam            | Home                  | Groundwater                    |                      |  |
| Snow                                                                    | Lake           | People                | Sea                            |                      |  |
| Sub-Category 1.2.2: Processes in WSN                                    |                |                       |                                |                      |  |
| Precipitation                                                           |                | Water Distribution    |                                |                      |  |
| Water Accumulation                                                      |                | Water Treatment       |                                |                      |  |
| Sub-Category 1.3: Sewerage System                                       |                |                       |                                |                      |  |
| Sub-Category 1.3.1: Components in Sewerage System                       |                |                       |                                |                      |  |
| Pipe                                                                    |                | Receiving Environment |                                |                      |  |
| Wastewater Treatment Plant                                              |                |                       |                                |                      |  |
| Sub-Category 1.3.2: Processes in Sewerage System                        |                |                       |                                |                      |  |
| Wastewater Collection                                                   |                | Wastewater Treatment  |                                |                      |  |
| Category 2: National Water Resources (NWR)                              |                |                       |                                |                      |  |
| Sub-Category 2.1: Current State of NWR                                  |                |                       |                                |                      |  |
| Water Resources Potential                                               |                | Water Pollution       |                                |                      |  |
| Sub-Category 2.2: Name of NWR                                           |                |                       |                                |                      |  |
| Aegean Sea                                                              |                | Mediterranean Sea     | Lake Van                       | Uzungöl              |  |
| Black Sea                                                               |                | Marmara Sea           | Lake Dipsiz                    |                      |  |
| Category 3: Relationship among Local, National, and Global (Sub)systems |                |                       |                                |                      |  |
| LWS- WSN                                                                |                | LWS -Biosphere        |                                | LWS -Atmosphere      |  |
| LWS -Hydrosphere                                                        |                | LWS -Geosphere        |                                | LWS - Anthroposphere |  |

**Figure 5.16**

*Cansu's Local Water System*



In terms of the functions of LWR, she explained they were used as survival, agricultural, and domestic purposes and they were not drinkable. River Kızılırmak was treated in the drinking water treatment plant, and then it was used for drinking.

### **Water Supply Network and Sewerage Systems**

During the second drawing task, Cansu explained where water coming from to her home as following:

Interviewer: Cansu, do you know where does your water come from to your home?

Cansu: Water comes to my home from River Kızılırmak. There is a small drinking water treatment plant that cleans its water. This treatment plant locates in the main county town. Our mayor told us when he visited our village. Then, clean water is distributed to storage tanks via invisible pipes and finally, it comes to our houses in the village. Everyone has small storage tanks near their houses.

On the other hand, Cansu explained discharging process of domestic wastewater as:



Interviewer: Cansu, where does your domestic wastewater go after using?

Cansu: Our domestic wastewater discharges in two ways. The wastewater discharged from our toilet goes into the sewerage system. I don't know what happens to this wastewater after the sewerage system. On the other hand, the wastewater discharged from kitchen and bathroom goes directly to the outside, to our garden. You can see flowing wastewater in your eyes in our garden. It is the same for all houses in our village. These wastewaters penetrate the soil and leak to the groundwater resources.

The analysis of her responses revealed that she only failed to identify a dam that accumulates water of River Kızılırmak and what happens to wastewater after collecting by the sewerage system.

The analysis of her responses revealed that Cansu had substantial amount of knowledge about the water systems at her hometown (8 components, three processes in WSN) except for sewerage system. In terms of sewerage system, she only identified one process, wastewater collection. She did not give detailed information about this process. The sources of information were mainly based on her observations and people's statements like mayor.

#### **5.3.2.2.2 Relationship between Local and Global (Sub)systems**

The analysis of Cansu's responses emerged five different relationship among local and global (sub)systems as (1) LWS- WSN; (2) LWS-Hydrosphere; (3) LWS-Geosphere; (4) LWS-Anthroposphere; and (5) LWS-Biosphere. Some of the relationships were appeared as triple or more combinations. Each combination was given below.

Cansu reported in detail that the water of her village's WSN was provided by River Kızılırmak as summarized in the previous section. She only failed to include dam and state what would happen their domestic wastewater discharged from their village. These statements revealed her notion on the relationship between LWS and WSN. She reflected her declarative knowledge and partial procedural knowledge on the interaction between LWS and WSN.

As I outlined in the functional systems literacy section, she thought that the total amount of water decreases on Earth. She exemplified this decrease by mentioning their

domestic use of water in her village. She mentioned that some of their wastewater in the village penetrates the soil and it would not be usable anymore. She emphasized that this situation affects all the world since it leads to a decrease in the total amount of water on Earth. This misinterpretation based on her observation might reflect her notion on the relationship between her LWS, hydrosphere, and geosphere. Additionally, she also mentioned that there were some agricultural areas and they were irrigated by well pumped from underground. The analysis of her responses revealed that Cansu had declarative knowledge, but she had some misconceptions in her procedural knowledge.

In terms of the relationship of LWS – Biosphere, she mentioned agricultural crops, trees, and animals used water of the River Kızılırmak. She also reported that there were a lot of plants near riverside and nobody watered these plants. They were green because of the River Kızılırmak. What is more, she mentioned how living organisms affect the local water system. She reported that animals and plants do not affect the local water system negatively as people do because they only use water for surviving. Plants and animals do not waste the water and use it efficiently. Therefore, she stated that they had no effect on the local water system. These indicators summarized above reflected her declarative knowledge on the relationship between her LWS and biosphere. Moreover, she explained partially the processes within those interactions.

The interactions between LWS and anthroposphere was another interaction revealed in her responses. She mentioned how local people water use affect the LWS as following:

In our village, wastewater that penetrates to soil does not go back to the natural cycle since groundwater cannot be used as far as I know. When we use water too much in summers, we face serious water shortage problems in our village. We learned that drinking water treatment plant has some difficulties to provide water in summers when the level of water in Kızılırmak decreases. What is more, people use the water to irrigate their garden in those times and this makes the water shortage problem worse. To overcome this water shortage, some people carry water from the main county town.

In this excerpt given above, she was mainly talking about the negative effects of people on her local water system. She complained about overconsumption of water during the summer seasons. Based on the analysis of responses, it can be summarized that she had declarative knowledge as well as procedural knowledge on the interactions between LWS and Anthroposphere.

In brief, when we examine [Figure 5.16](#) as well as her responses in different data collection instruments, we can summarize her cultural systems literacy as following table.

#### **5.3.2.2.3 Mapping the Interactions of the Categories in Cansu's Cultural Systems Literacy**

To explore the interactions among the categories in CUSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.17](#) revealed the map.

Cultural systems literacy of Cansu in terms of local water system can be summarized based on the content analysis of this section as following:

- [Table 5-9](#) revealed that Cansu have both declarative and procedural knowledge on the basic mechanisms of her local water system.
- [Figure 5.17](#) revealed that *Relationship between Local and Global Systems* and *Component in WSN* had most interactive categories among the others. In other words, while Cansu was talking about the basics of local water system, she mostly used components of WSN and its relationship among the other systems.

In the next section, Cansu's critical systems literacy in water context will be given.

**Table 5-9***Summary of Cansu's Cultural Systems Literacy in Water Context*

| Categories / Codes*                                  | Declarative<br>/Procedural | Fully<br>Correct<br>Statement | Partial<br>Correct<br>Statement | Incorrect  |              | Don't<br>Know |
|------------------------------------------------------|----------------------------|-------------------------------|---------------------------------|------------|--------------|---------------|
|                                                      |                            |                               |                                 | Consistent | Inconsistent |               |
| <b>Components of LWS</b>                             | Declarative                | ✓                             |                                 |            |              |               |
| <b>Local Water Resources</b>                         |                            |                               |                                 |            |              |               |
| <b>Name of LWR</b>                                   | Declarative                | ✓                             |                                 |            |              |               |
| <b>Functions of<br/>LWR</b>                          | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 | ✓                             |                                 |            |              |               |
| <b>Water Supply Network and Sewerage System</b>      |                            |                               |                                 |            |              |               |
| <b>Components</b>                                    | Declarative                |                               | ✓                               |            |              |               |
| <b>Processes</b>                                     |                            |                               |                                 |            |              |               |
| <b>Water<br/>Accumulation</b>                        | Declarative                |                               | ✓                               |            |              |               |
|                                                      | Procedural                 |                               | ✓                               |            |              |               |
| <b>Water<br/>Distribution</b>                        | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 | ✓                             |                                 |            |              |               |
| <b>Drinking<br/>Water<br/>Treatment</b>              | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 |                               | ✓                               |            |              |               |
| <b>Wastewater<br/>Collection</b>                     | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 |                               |                                 |            |              | ✓             |
| <b>Wastewater<br/>Treatment</b>                      | Declarative                |                               |                                 |            |              | ✓             |
|                                                      | Procedural                 |                               |                                 |            |              | ✓             |
| <b>Relationship between Local and Global Systems</b> |                            |                               |                                 |            |              |               |
| <b>LWS-WSN</b>                                       | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 |                               | ✓                               |            |              |               |
| <b>LWS - Hydrosphere</b>                             | Declarative                |                               | ✓                               |            |              |               |
|                                                      | Procedural                 |                               |                                 | ✓          |              |               |
| <b>LWS - Biosphere</b>                               | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 |                               | ✓                               |            |              |               |
| <b>LWS -<br/>Anthroposphere</b>                      | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 | ✓                             |                                 |            |              |               |
| <b>LWS-Geosphere</b>                                 | Declarative                | ✓                             |                                 |            |              |               |
|                                                      | Procedural                 |                               |                                 | ✓          |              |               |
| <b>TOTAL (n)</b>                                     |                            | 13                            | 7                               | 2          | 0            | 3             |
| <b>Declarative (D)</b>                               |                            | (10D, 3P)                     | (3D, 4P)                        | (2P)       |              | (1D,<br>2P)   |
| <b>Procedural (P)</b>                                |                            |                               |                                 |            |              |               |

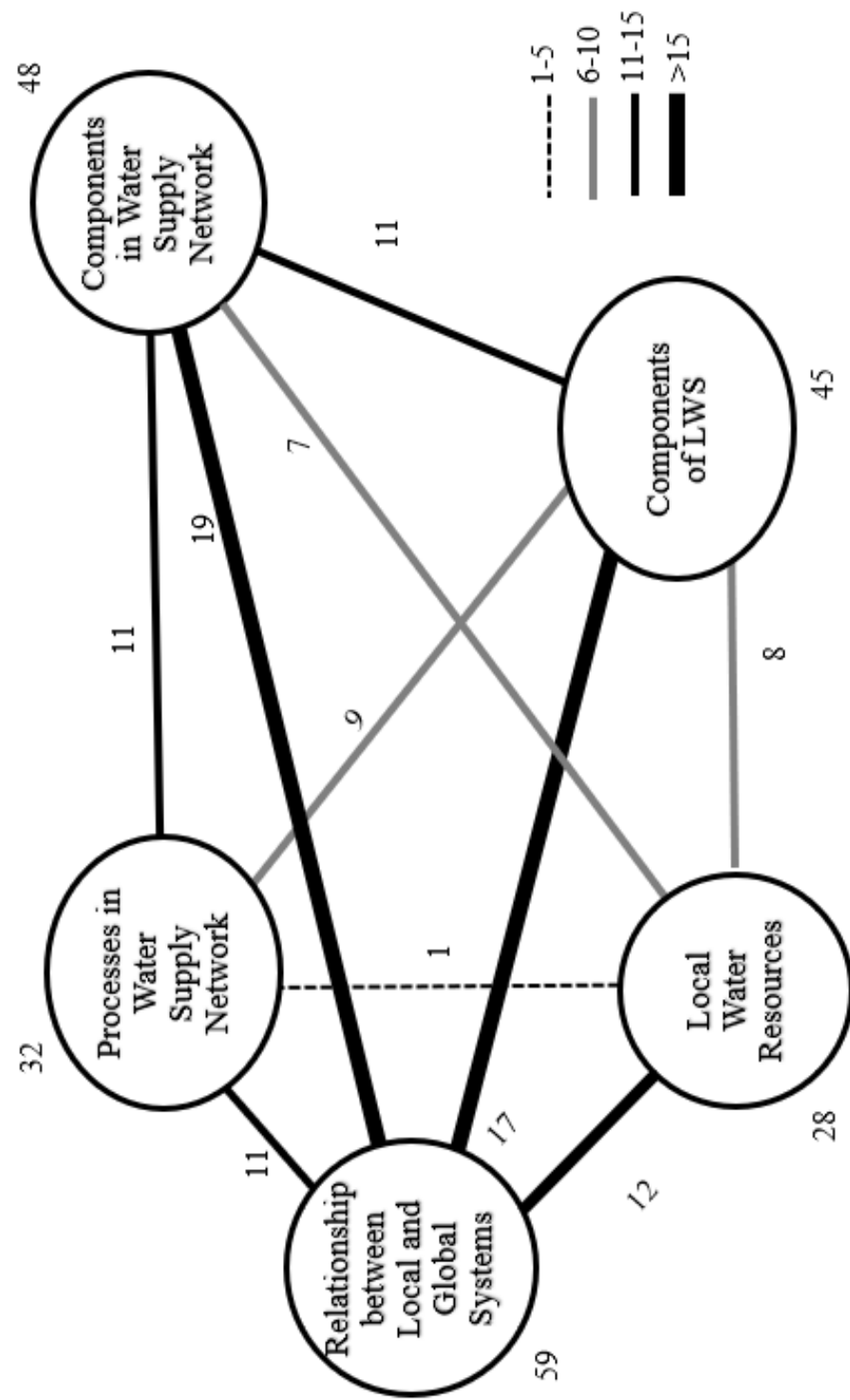
\* Not all categories/codes were given in this table since some of them were not observed in all participants

\*\* Even though participants have partially correct response in declarative knowledge, (s)he has fully correct response for the procedural knowledge.

\*\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception. OR they stated that they did not know the answer but tried to answer, though.

**Figure 5.17**

*Mapping the Interactions among the Categories of Cansu's Cultural Systems Literacy*



### 5.3.2.3 Cansu's Critical Systems Literacy

The findings in this section will be given under these two themes as well as their categories. Table 5-10 indicated the themes, categories and codes of Cansu's critical systems literacy in water context.

#### 5.3.2.3.1 Advance Mechanisms of Water System

The theme of advance mechanisms of water system were summarized as following categories: dynamic nature of water system, causal dynamics and feedback loops, evolution of the system, and complexity of the water system. Each category was given in the subsequent sections.

##### 5.3.2.3.1.1 Dynamic Nature of Water System

As stated in the section of Quantity of Water, Cansu was not aware of that the total volume of the water is almost constant. This misconception was also emerged in this category. The analysis of her responses revealed that her mental model on the dynamic effects of unconscious use of water was constructed based on her misconception. Her response on time delays and redistribution of water in the water system was given below.

Interviewer: ... So, how water cycle would be affected when we use it unconsciously?

Cansu: It is affected negatively. As I said before, some of our domestic wastewater is discharged into our garden and penetrates to the soil. This wastewater, then, leaks to the groundwater and groundwater resources do not cycle again. It is not feasible to reach them. As a result, the total amount of water on Earth decreases. ... *(the conversation continues after the excerpt)* ... For example, when people use the water unconsciously, it also leads to decrease in the amount of precipitation.

In another instance, while we were talking about the probability of the reversing the negative effects of climate change on water supply, she mentioned the time delays in water system as following:

It is not reversible, in my opinion because we couldn't return the water back. Even if we use less water to provide our needs starting today, it requires many years to rebalance itself *(she referred water system)*. It already changed and we are trying to reverse this change.

**Table 5-10***Themes, Categories and Codes – Cansu's Critical Literacy*

| Theme 1: Advance Mechanisms in Water System                         |                                         |                 |
|---------------------------------------------------------------------|-----------------------------------------|-----------------|
| Category 1.1: Dynamic Nature of Water System                        |                                         |                 |
| CRDN111: Time Delay                                                 | CRDN112: Redistribution of Water        |                 |
| Category 1.2: Causal Dynamics and Feedback Loops                    |                                         |                 |
| CRFL121: Simple Open Loop                                           | CRFL123: Balancing Loop                 |                 |
| CRFL122: Reinforcing Loop                                           | CRFL124: Open Loop with multiple causes |                 |
| Category 1.3: Evolution of Water System                             |                                         |                 |
| CREV131: Decaying                                                   | CREV133: Toward higher organization     |                 |
| CREV132: Steady state                                               |                                         |                 |
| Category 1.4: Complexity of Water System                            |                                         |                 |
| Sub-Category 1.4.1: Interruptions in the Water System               |                                         |                 |
| CRCO1411: Climate Change                                            | CRCO1412: Hidden Use of Water           |                 |
| Sub-Category 1.4.2: Layers of Complexities                          |                                         |                 |
| CRCO1421: Environmental                                             | CRCO1424: Health                        |                 |
| CRCO1422: Economic                                                  | CRCO1425: Educational                   |                 |
| CRCO1423: Social                                                    | CRCO1426: Governmental                  |                 |
| Theme 2: Invisible Elements of Human System                         |                                         |                 |
| Category 2.1: Beliefs on Water Use                                  |                                         |                 |
| CRBL211: Self-use of water                                          | CRBL213: Sources of Beliefs             |                 |
| CRBL212: Collective use of water                                    |                                         |                 |
| Category 2.2: Self-efficacy towards Efficient Water Use             |                                         |                 |
| CRSE221: High                                                       | CRSE222: Low                            |                 |
| Category 2.3: Motive Concern                                        |                                         |                 |
| CRMC231: Social Altruistic                                          | CRMC233: Biospheric                     |                 |
| CRMC232: Egoistic                                                   |                                         |                 |
| Category 2.4: Action Strategies for Efficient Water Use             |                                         |                 |
| CRAC241: Persuasion                                                 | CRAC244: Reuse of water                 |                 |
| CRAC242: Water loss prevention                                      | CRAC245: Recycle of water               |                 |
| CRAC243: Reduce of water use                                        | CRAC246: No action                      |                 |
| Category 2.5: Emotional response                                    |                                         |                 |
| CREM251: Anger                                                      | CREM253: Happiness                      | CREM255: Apathy |
| CREM252: Sadness                                                    | CREM254: Proud                          |                 |
| Category 2.6: Motivational Orientation for Sustainable Use of Water |                                         |                 |
| CRMO261: Intrinsic motivation                                       | Amotivation                             |                 |
| CRMO262: Extrinsic motivation                                       |                                         |                 |

Overall, the analysis of her responses indicated that her misconception “the total amount of water is decreasing” dominated her mental model on the time delays and redistribution of water in the water system. Although she was aware of time delays in water system, she attributed these delays to the decrease in the total amounts of water. Moreover, she did not consider groundwater as a dynamic concept. She presumed that groundwater was static water that remained below the Earth surface and not be a part of the water cycle.

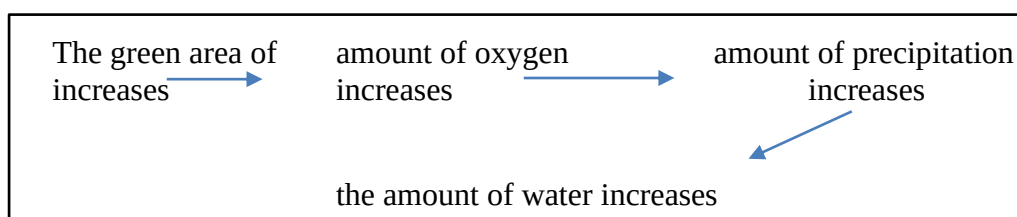
#### 5.3.2.3.1.2 Causal Dynamics and Feedback Loops

Causal dynamics were traced during the interview. During the interview, Cansu mentioned implicitly two simple open loops, one open loop with multiple causalities, and one another chain events including a simple reinforcing loop.

Cansu reflected her notion of causality with an open loop while she was explaining the importance of plants to the water system. She stated that “*As far as I know green plants increase the amount of the oxygen. This increase also leads to another increase in the amount of precipitation. In this way, we have more water.*” Cansu’s statement of causality can be classified as an open loop. We could visualize it as following:

**Figure 5.18**

*Cansu’s Open Loop on Causalities in Water System*



In another instance, while she was talking about the hidden use of water, she stated that:

Since I am eating that hamburger, I am responsible for the water consumption for it. If I did not buy it, there will be more water on Earth. The foods are manufactured based on our demands. If we eat less, it will be produced less, and less water will be spent for manufacturing the foods.



Cansu's statement of causality can be classified as an open loop. We could visualize it as following:

**Figure 5.19**

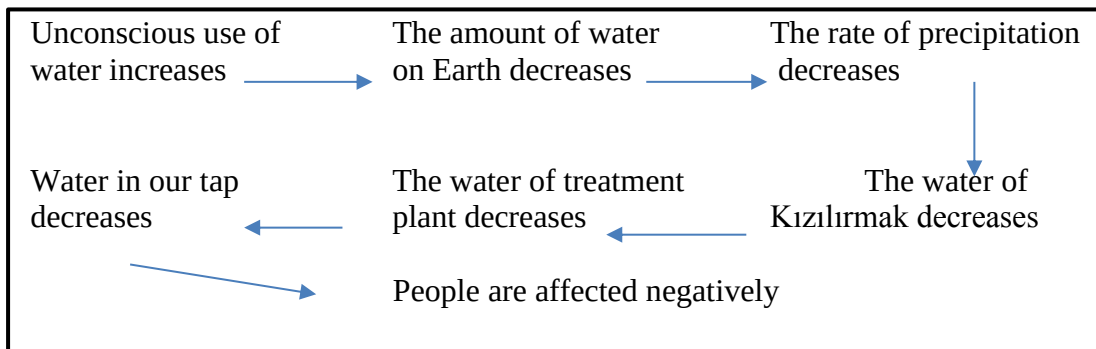
*Cansu's Open Loop on Causalities in Water System*



Cansu mentioned some chain events about what would happen when people use the water unconsciously under the section of “*Relationship with Local and Global (Sub)Systems*” The summary of these causal dynamics can be visualized in [Figure 5.20](#). The figure revealed that disruption or failure in water system will eventually have negative effects on human life.

**Figure 5.20**

*Cansu's Open Loop with Multiple Causalities*



In another context, Cansu explained implicitly a simple reinforcing loop while she was talking about the effects of climate change and ozone layer hole. She constructed a causality based on the misconception of ozone layer hole. Her response was following:

Cansu: ... Droughts emerge because of the hole in the ozone layer since temperature increases due to that hole (*she referred more sunlight comes through the hole*). This also leads to glacier melt at the same time. This melting leads to climate change. Climate change have negative effects on all living organisms. At first, plants and crops

are affected. This situation has negative effect on people's lives. And the rest of the living organisms will be affected too.

Interviewer: Why the other living organisms will be affected after people?

Cansu: I mean, the agriculture... As grains will not be harvestable anymore, people couldn't find something to eat. It is the same for the animals. Animals also suffer from hunger and these chain events intensifies the drought itself.

The visualization of this simple reinforcing loop was given as a part of [Figure 5.21](#). Note that red arrows represented simple reinforcing loop. In the figure, Cansu's notion was summarized as when the hole in the ozone layer expands, then the temperature also increases. These events have two consequences. The first one is glacier melting which contributes to the climate change. Climate change, on the other hand, affects badly the living organisms. The second consequence is drought. Drought also affects the living organisms. At this point, negative effects of drought on the living organisms, in turn, intensify the drought itself and this creates a loop.

To sum up, Cansu revealed her notion of causality in a system by explaining chain events in simple open loops and reinforcing loop. While she was explaining her notion on the causalities, she attributed these causalities to the effects of living organisms.

#### **5.3.2.3.1.3 Evolutionary Processes in Water System**

Cansu addressed possible evolutionary scenarios for her local water system and the global water system. The sample excerpt for her local water system's evolutionary change was following:

I think it is going to be not so good. In the case of decrease in the amount of precipitation, the River Kızılırmak won't be able to send water to our drinking water treatment plant. We are going to suffer from drought. Local people do not learn a lesson from mistakes. Our water supply has been cut off in summers due to our unconscious use of water. I think that our water will be dry up one day if it goes like this and we will suffer in the end.

While she was talking about the future of her local water system, she used her observation about cutting off in their water supply in summers to make inference about the evolution of her local water system. Overall, her statements revealed that she interpreted the evolution of her local water system as decaying since she claimed that

it would be worse than today if local people did not change their behavior. In terms of global aspects, she remained undecided:

Provided that recycling of conscious use of water, the future of the global water system would be promising. However, I don't know whether people use the water consciously or not. In my hometown, they don't, but there are people in here (*referring her school located in the city center*) who use water consciously. Nevertheless, it is hard to foresee if all the people on Earth use the water wisely or not. If they did not, then the life on Earth will cease in the future.

She seemed that even though she was prone to decide decaying due to human use of water, she also assumed that there may be some people using water consciously. To sum up, the analysis of her responses revealed that she predicted that the evolutionary state of her local water system is decaying due to unconscious use of water of local people, but she was neutral about the future of the global system.

#### **5.3.2.3.1.4 Complexity of the Water System**

##### *Climate Change and The Water System*

The analysis of this part revealed that Cansu could be able to detect interruptions in the water system and some of the layers of its complexity in this story. I asked to her “*What happened to the water system in this story?*” Her rationale was following:

Cansu: Overconsumption of water leads to these problems.

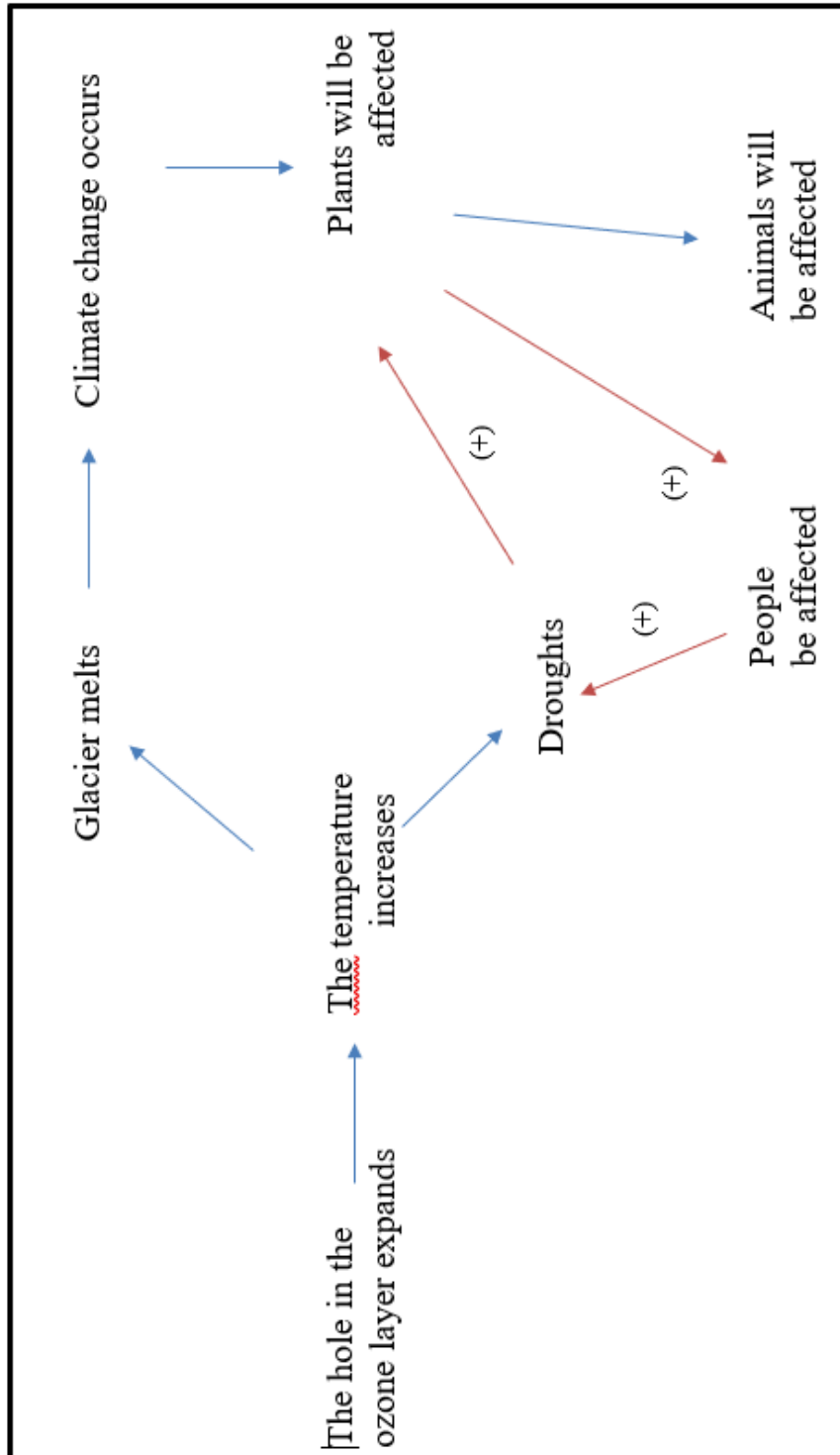
Interviewer: Okay, thank you. So, it was written that the seasons began earlier than expected. What could be the reason for it?

Cansu: Climate change, in my opinion.

Cansu detected the failure of the water system within the case as climate change. In terms of layers of complexities, she mentioned only the effects of climate change on the social and environmental perspectives. Sample excerpt (p.221) was given earlier. However, she failed to give detail on the mechanism of the climate change. She identified two different layers of complexity in the water system as social and environmental perspectives.

**Figure 5.21**

*Cansu's Chain Events of Causalities and Reinforcing Loops*



### *Hidden Use of Water and The Water System*

When I asked Cansu about the term “hidden use of water” during the interview, she said she heard this term in one of the presentations in the course of “Social Activities” offered by her high school. She defined the term as *“For example, there are water consumption while producing foods like tomatoes. We do not see this water consumption, but we consume that water too.”* Consecutively, I asked to her whether she know the exact amount of water for producing 1 kg of tomatoes she responded that *“I don’t remember but it was too much”*

I asked Cansu to explain water consumption in a hamburger. She responded as following:

Interviewer: What about, for instance, a hamburger? Do we spend water for it?

Cansu: Foods in hamburger are grown in the soil and they are irrigated. It is same for the bread. There is also water consumption in producing the bread. On the other hand, meat comes from animals and animals drink water for surviving.

Interviewer: So, do you remember how much water do a hamburger have in total?

Cansu: No, but I know that it has more water than the fruits and vegetables’ production.

Interviewer: OK, when you think about the process of hamburger production, who are responsible for the consumption of water?

Cansu: The farmers who raise them and cleaners who clean the foods... Since I am eating that hamburger, I am responsible too for the water consumption for it. If I did not buy it, there will be more water on Earth. The foods are manufactured based on our demands. If we eat less, it will be produced less, and less water will be spent for manufacturing the foods.

The analysis of the conversation revealed that Cansu had correct declarative knowledge about the term “hidden use of water”. However, when more elaborative questions were asked about water consumption in a product, for example, she had the ability to infer consumption of water at some level, but she neglected the water for animals’ grain, hamburger’s packaging process as well as wastewaters spent for the production. This indicated that she had procedural knowledge partially about the processes during the production. Besides, she stated that she is responsible for the water consumption since she bought it.

### 5.3.2.3.2 Invisible Elements of Human System

In this section, the findings were given within the categories of beliefs about water use, action strategies for efficient water use, self-efficacy beliefs towards efficient water use, emotional responses, motive concerns, and motivational orientation for sustainable water use.

#### 5.3.2.3.2.1 Beliefs on Water Use

##### *Beliefs on Self-use of Water*

Self-use of water was traced in the interview part. The analysis of Cansu's responses indicated that she had descriptive belief, inferential belief and informational belief. These beliefs were summarized one by one with their sources of the beliefs.

Cansu had inferential belief based on her descriptive belief and her inferences on her direct experiences. She believed that (1) she used water efficiently most of the time and (2) she was one of the responsible water users. She stated that she was careful in both direct use and hidden use of water. To understand the rationale of her descriptive belief, I asked to her in which activities does she consume water in a day. She stated that:

I use water in bathroom in my dormitory and the restroom in my school. I also consume water while I am eating my meals, and these include both direct and hidden use of water. I admit that I sometimes consumes water inefficiently like consuming hamburger or taking longer showers. Nevertheless, when I feel that I consume too much water, I stop doing it. I believe I am a responsible user.

*... (the conversation continues after the excerpt) ...*

I don't let water leakage in the dormitory. When I see an open tap, I turn off it. If a tap is broken, then I inform the plumber of the dormitory and he fixes it.

Analysis of her responses revealed that she formed her inferential beliefs based on her daily water use. She talked about what she did when she realized the wasting of water. Accordingly, she inferred that she was a responsible user.

Cansu had another inferential belief that she is more conscious than other people in her village by means of water consumption. She attributed this belief to her descriptive beliefs. She formed descriptive beliefs based on her direct experiences for the water consumption not only herself but also other people in her village. Based on these, she inferred that she used the water more consciously than the other people. Her descriptive belief related to other people will be given in “*beliefs on collective use of water*”.

She reflected her informational belief while she was talking about where she sees herself in the water system. She believed that “*I am in the middle of the water system*” and explained this belief based on outside sources as following:

I am recycling water with my family. Therefore, I believe that I am in the middle of the water system because cycles don't have starting/ending points. We learnt this information in the lecture before. My family and I constructed a recycling system in our garden. Our domestic wastewater flows to our trees and our trees use that water. We put some pipes to that system so that it reaches to the trees. Eventually, I do not consume extra clean water to irrigate them except for very hot days in summers.

The analysis of her responses indicated that the sources of her informational beliefs as lecturers and her family. In short, she had descriptive beliefs, inferential belief, and informational belief. While she was sharing them, she also gave the sources of her beliefs. In other words, she mentioned her direct experiences, inferences, and outside sources related to those specific beliefs.

#### *Beliefs on Collective Use of Water*

In this part, the role of people in water system was asked to trace Cansu's beliefs on collective use of water. She had descriptive and inferential beliefs on this context. In terms of the role of people in the water system, she had a inferential belief that “*people use water inefficiently*”. According to her, the local people in her hometown did not use wisely and correspondingly, they suffer from water shortage problems in summers. She elaborated inefficient use of water as following: “*Me and my family recycle our*

*domestic wastewater. However, this is not the case for the other people. Their domestic wastewater leaks to the groundwater and the amount of water decreases on Earth.”*

Cansu had also another inferential belief that “*the people will not take lesson continue to consume water inefficiently*”. This inference was based on the descriptive belief given above. She explained further as following:

To overcome water shortage problem, we started a campaign in our middle school, and nobody listens to us. We prepared a project related to use of well water located near the agricultural field in the village aiming to prevent water shortage problems in summers. The municipality put our project into practice, but nobody uses the well water. They think that the well water is dirty. They continue to use the water coming from the drinking water treatment plant and we still suffer from water shortage in summers. They carry water from the main county town when water shortage problem appears.

Her statements revealed that her inferential belief that “the people will not take lesson from the past and continue to consume water inefficiently” was based on her inference from failure of a project and relapsing water shortage problems. These events formed her descriptive belief of her given above. Then, she guessed the probable collective use of water in the future based the descriptive belief. In short, Cansu had inferential beliefs based on her descriptive beliefs and inferences on the collective use of water.

#### **5.3.2.3.2.2 Action Strategies for Efficient Water Use**

As Cansu reported that she did not remember the context of sustainability, the interview was built based on her action strategies for efficient water use. Correspondingly, I asked her to explain whether she set a goal related to efficient water use in her daily life. Her response was following:

Cansu: I use only the amount of water that I need. In general, I don’t use water more than I need. I turn off the tap when I wash my hands and face. On the other hand, I don’t consume products too much to monitor my hidden use of water.

*... (the conversation continues after the excerpt) ...*

As I said before, we recycle our domestic wastewater in our garden. In the dormitory, on the other hand, I also inform the plumber in the case of leakage. Also, I turn off the open taps in the public restrooms.



The sample excerpt revealed that her action strategies were related to her direct use and hidden use of water. She generally mentioned how she reduce her water use in daily activities. In addition, she also reported that how she monitored her hidden use of water and water loss prevention. As previously reported, she stated that she participated in a project in the middle school related to water pollution and incentive of well water use in her village. These participations were classified as persuasion to other people. In short, persuasion, water loss prevention, reduce, and recycle of water were Cansu's self-reported action strategies to use water efficiently.

#### **5.3.2.3.2.3 Self-Efficacy Beliefs towards Efficient Water Use**

While she was talking about her action strategies given above, she believed that she used water only when she needs it. This was one of the indicators to having high self-efficacy towards being efficient user of water. She gave detailed information about how she uses water efficiently in terms of direct and hidden use of water. Thus, it also indicated that her self-efficacy was based on her actual behavior.

#### **5.3.2.3.2.4 Emotional Response**

Her emotions related to effects of people on the water system were asked. She said she was sad for the River Kızılırmak since it level of water decreases due to unconscious use of people. On the other hand, she feels proud for what her family and her was doing for the recycling of water for the sake of the water system. The analysis of her responses indicated that sadness and proud were the two emotional responses that she had related to the water system.

#### **5.3.2.3.2.5 Motive Concern**

To reveal the motive concerns of Cansu on the importance of water system, several questions were asked during her interview. First, the importance of water system was asked. She explained her view as following:

Of course, it is important because human life depends on water. Unless water was supplied, people would die After all, 97% of our body includes water...It is same for

the animals and plants. They would die, too. Animals needs water for drinking and cleaning purposes. In my hometown, there are lots of plants. Unless we watered them for one week, they would wither.

While Cansu shared her ideas about maintenance of water system, she emphasized human beings, animals, and plants, who are possibly be affected from disruption in the water system. This response was an indicator of his biospheric and social altruistic motive concern.

During different instances in her interview, her social altruistic motive concern was dominant compared to biospheric motive concern. Some of them will be given under the section of “Motivational Orientation”. In short, Cansu hold different motive concerns about the present state of water system, but social altruistic value orientation was dominant in her responses.

#### **5.3.2.3.2.6 Motivational Orientation**

As presented in the previous sections, Cansu used water efficiently both in her village and in her dormitory. She was careful about not to waste water and shared her strategies. In terms of motivational aspect, it was asked to Cansu that the sources of her motivation if any to use water efficiently. Her specific answer related to that question was following:

Cansu: If I didn't use it efficiently, there will be no water in the future not only for us but also for the next generations. Past generations had not used the water efficiently and the amount of water has been decreasing, in my opinion. Unless we used it wisely, there will be no water. As we will not be able to survive without water, I chose to be efficient user.

The analysis of her responses indicated that she had *external motivation*. In her case, her water consumption behavior was autonomous, volitional, persistent but still, extrinsically motivated.

#### 5.3.2.3.3 Summary of Cansu's Critical Systems Literacy in Water Context

The analysis of Cansu's critical systems literacy in water context were given in two themes. In terms of *advance mechanisms of water system*, Cansu's explanations were categorized in four categories. In term of dynamic nature of water system, Cansu reflected her awareness on time delays in water system. However, her rationale about how these dynamical mismatches occur based on her misconception. On the other hand, she exemplified causal dynamics by explaining them as two simple open loops, one open loop with multiple causalities, and one another chain events including a simple reinforcing loop. In terms of evolutionary processes in the system, she mentioned negative effects of unconscious use of water was an indicator for *decaying* state of the water system, but she was neutral about the future of the global system. Last, Cansu's reflections related to the real story and the concept of hidden use of water were indicators of her notion on the complexity of the water system. She detected climate change and hidden use of water as two disruptions in the water system. She failed to give detail on the mechanism of the climate change. She mentioned the layers of complexities as social and environmental dimensions. In terms of hidden use of water, she had partially correct procedural knowledge about the processes during the production. Besides, she stated that she is responsible for the water consumption since she bought it.

Under the theme of *invisible elements of human system*, Cansu's responses were examined by means of six categories. In terms of beliefs on water consumption behavior, she reflected her beliefs on self-use and collective use of water. She gave detailed information about the sources of her beliefs. She had descriptive beliefs, inferential beliefs, and informational beliefs related to self-use of water. Descriptive beliefs were based on her daily life experiences. She attributed her inferential belief to her descriptive beliefs. The sources of her informational beliefs as lecturers and her family. In terms of action strategies for efficient water use, she gave detailed information on her water use for both hidden and direct use of water. Her statements also revealed that she had high self-efficacy while she mentioned her direct and hidden

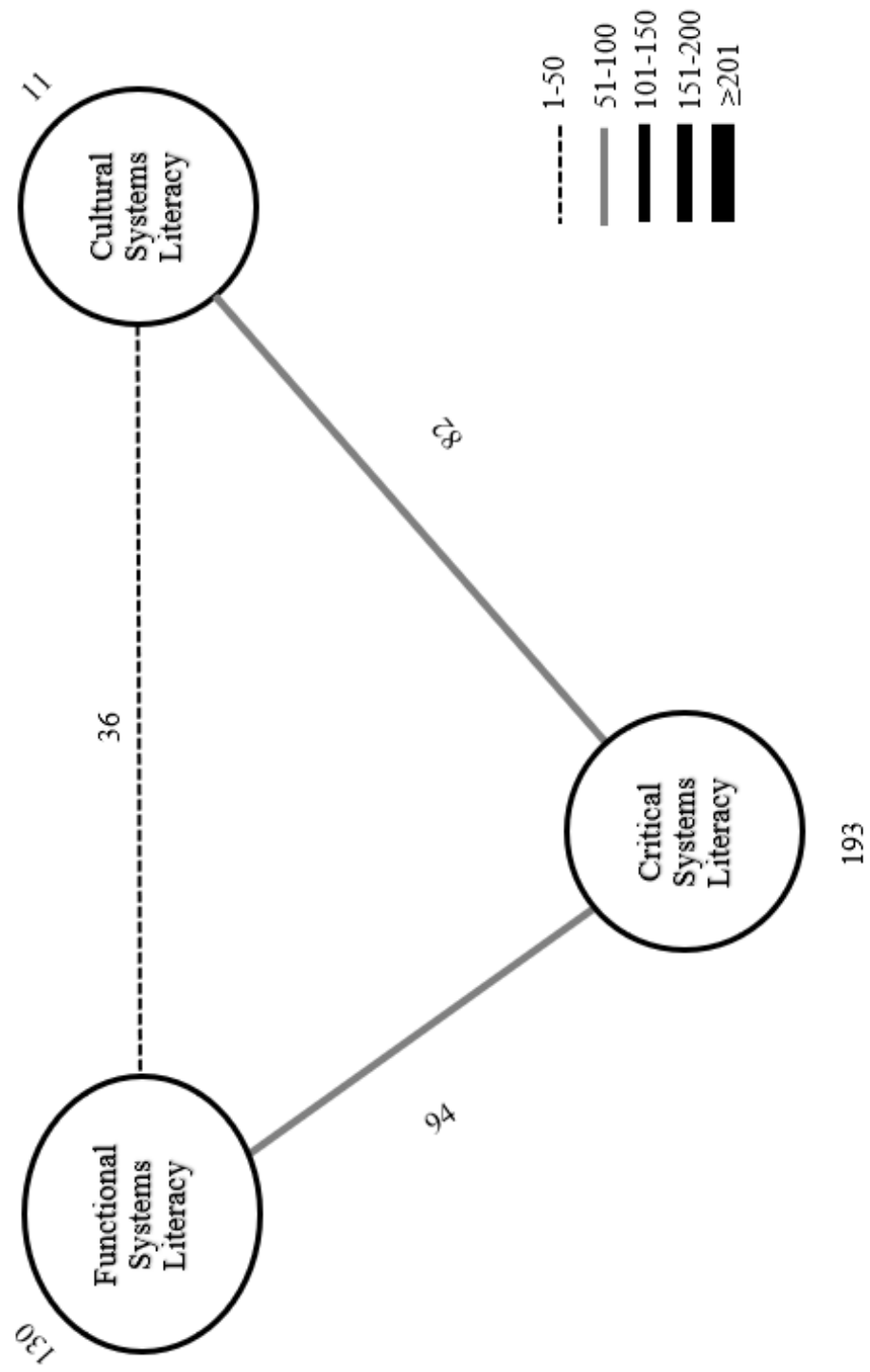
use of water. Sadness and proud were the two emotional responses that she had related to the water system. Cansu hold different motive concerns about the present state of water system, but social altruistic value orientation was dominant in her responses. Last, she attributed her motivation about efficient use of water to consider the importance of water for next generation. Thus, she had extrinsic motivation since she exhibited a behavior because it is regulated by giving importance to the next generation's life standards. Her water consumption behavior was autonomous, volitional, persistent but still, extrinsically motivated.

#### **5.3.2.4 Mapping the Interactions of the Categories in Cansu's Systems Literacy**

To explore the interactions among the FSL, CUSL, and CRSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.22](#) revealed the map. The order of the interactions from highest to the lowest among the elements of systems literacy was FSL-CRSL, CUSL-CRSL and FSL-CUSL. The interactions among the elements of systems literacy of Cansu in terms of water system can be summarized based on the content analysis of this section as following:

- She had substantial amount of knowledge about the basic mechanisms of her local water system (CUSL) compared to basics of the water system (FSL).
- [Figure 5.22](#) revealed that *Critical Systems Literacy* appeared mostly in his responses among the others.
- *Functional Systems Literacy* and *Cultural Systems Literacy* had similar number of interactions with *Critical Systems Literacy* compared to the other participants.

**Figure 5.22**  
*Mapping the Interactions among the Cansu's Systems Literacy Elements in Water Context*



### 5.3.3 Case 3: Ahmet

Ahmet was born in 2005. He is a ninth-grader male student in a private high school located in a seashore city. His national entrance exam score was 438 out of 500 points which corresponded to top %6 of the applicants. His hobbies are playing chess and piano.

Ahmet's mother is a commercial lawyer; his father is an associate professor at a faculty of law. Their house is located at a coastal city and it is the most third crowded city in the country. Besides, Ahmet mentioned that they also have two houses more, one is at the seaside, while the other is near a village. He reported that there is a small creek around their house in the village. Moreover, they have henhouse and a small hobby garden to plant some crops. During his middle school, he had no other specific activity or interest in water context. In terms of the concept of the sustainability, Ahmet reported that he has heard about sustainability from the middle school but not remember its scope in detail. In the ninth grade before I collected data from him, water in living organisms was taught in his biology course.

I worked with Ahmet in two sessions. The responses of Ahmet through the conception test, first drawing task, and interview questions reflected some indicators related his systems literacy. The analyses of his responses were given below under the elements of functional systems literacy, critical systems literacy, and cultural systems literacy.

#### 5.3.3.1 Ahmet's Functional Systems Literacy

The analysis of his responses in conception test, first drawing task and interview phase 1 revealed his functional systems literacy in five categories as (1) general characteristics of water; (2) power sources of water cycle; (3) components of water cycle; (4) processes of water cycle and (5) relationship between the Earth systems. [Table 5-11](#) indicated codes and categories for his functional systems literacy in water context.

**Table 5-11***Themes, Categories and Codes: Ahmet's Functional Systems Literacy*

| <b>Theme - Basics of Water System</b>                         |                                     |
|---------------------------------------------------------------|-------------------------------------|
| <i>Category 1: General Characteristics of Water</i>           |                                     |
| FGC11: Quantity of Water *                                    | FGC14: Water and Living Organisms   |
| FGC12: Cyclic Nature                                          | FGC15: Relational Responsiveness    |
| FGC13: Properties of Water                                    |                                     |
| <i>Category 2: Power Sources of Water Cycle</i>               |                                     |
| FPS21: Sun                                                    | FPS23: Gravity                      |
| FPS22: Wind**                                                 |                                     |
| <i>Category 3: Components of Water System</i>                 |                                     |
| FC31: Plant                                                   | FC317: Cloud                        |
| FC32: Sun                                                     | FC318: Rain                         |
| FC33: Water                                                   | FC319: Snow                         |
| FC34: Animal                                                  | FC320: Fog                          |
| FC35: Human                                                   | FC321: Hail                         |
| FC36: Ocean                                                   | FC322: Freshwater                   |
| FC37: Sea                                                     | FC323: Ice                          |
| FC38: Water Vapor                                             | FC324: Well                         |
| FC39: River                                                   | FC325: Lake                         |
| FC310: Glacier                                                | FC326: Stream                       |
| FC311: Spring                                                 | FC327: Dew                          |
| FC312: Soil                                                   | FC328: Algae                        |
| FC313: Wetland                                                | FC329: Creek                        |
| FC314: Rock                                                   | FC330: Puddle                       |
| FC315: Groundwater                                            | FC331: Mountain                     |
| FC316: Aquifer                                                |                                     |
| <i>Category 4: Processes of Water System</i>                  |                                     |
| FP41: Evaporation                                             | FP410: Surface flow                 |
| FP42: Condensation                                            | FP411: Melting                      |
| FP43: Sublimation                                             | FP412: Freezing                     |
| FP44: Evapotranspiration                                      | FP413: Frosting                     |
| FP45: Respiration                                             | FP414: Dissolution                  |
| FP46: Precipitation                                           | FP415: Transpiration                |
| FP47: Penetration                                             | FP416: Capillarity                  |
| FP48: Infiltration                                            | FP417: Photosynthesis               |
| FP49: Underground flow                                        |                                     |
| <i>Category 5: Interactions among the Earth (Sub)Systems*</i> |                                     |
| FRES51: Hydrosphere—atmosphere                                | FRES55: Hydrosphere-anthroposphere  |
| FRES52: Hydrosphere—geosphere                                 | FRES56: Water cycle- nitrogen cycle |
| FRES53: Hydrosph. (continental)—hydrosph. (marine)            | FRES57: Water cycle- oxygen cycle   |
| FRES54: Hydrosphere—biosphere                                 | FRES58: Water cycle – carbon cycle  |

\*black codes: emerged from Ahmet's responses

\*\*pale codes: not apparent in Ahmet's responses

#### 5.3.3.1.1 General Characteristics of Water

The first category in explaining Ahmet's functional systems literacy was general characteristics of water. His answers for the questions for this session were given by means of quantity of water, its cyclic nature, properties of water, relational responsiveness, and water and living organisms.

##### ***Quantity of Water***

Ahmet correctly responded that most of the water on Earth is found in oceans. In a similar manner, he correctly chose that the amount of water does not change on Earth (please see ). In his interview, he elaborated his notion on the decrease in the total amount of water on Earth in different contexts as *"The amount of water does not change on Earth. We use the same water repeatedly."* The analysis of his answers in different forms of questions (conception test items, interview questions), revealed that he identified the highest proportion stored in the oceans. Moreover, he stated that the amount of water is almost constant on Earth. He explained it in terms of both declarative and procedural knowledge.

##### ***Cyclic Nature***

For obtaining information about his notion on the cyclic nature of water, the first drawing task, conception test, and interview questions was analyzed. In his drawing, he used arrows to show how water cycles. Water evaporated; precipitated both on the land and the water resources; and then, water flowed to sea from the mountains via rivers. The cyclic nature was represented by arrows. The figure was given in [Figure 5.23](#).

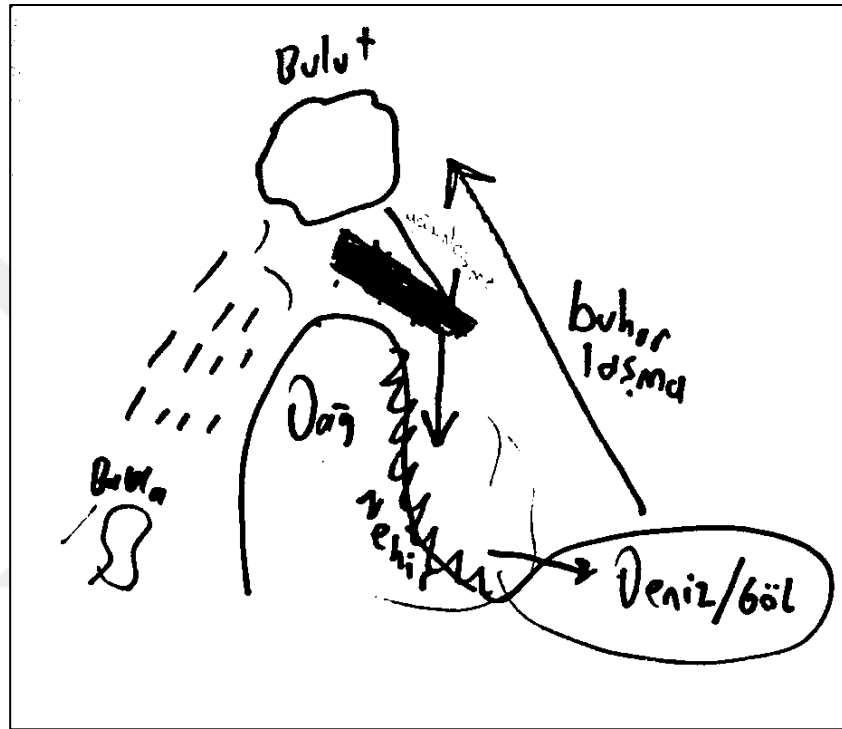
After the first drawing task ended, I asked him to explain what he drew. He explained how water cycle occurs as *"Condensed water vapor in the clouds goes into the lakes or seas via creeks and rivers. Then, it evaporates and goes to the clouds again."* In another instance, he explained the cyclic nature as *"Lakes and seas are formed by the water coming from the clouds. Similarly, clouds would have not been formed, if lakes*



and seas did not exist. This forms a vicious circle. Hence, there is no starting point of the water cycle.”

**Figure 5.23**

*Ahmet's Drawing of Water Cycle*



Analyzing of both his drawing and explanation revealed that he explained partially correct the cyclic nature of the water since he failed to indicate the evaporation from the land. His responses indicated that water only evaporates from the surface water resources. Moreover, he also failed to include solid state of water as well as groundwater while he was explaining how water cycle occurs. During the interview, he declaratively stated glaciers as “*potential water resources as a backup plan in case of water scarcity*”. Consistent with these, Ahmet chose the answer that there is no starting/ending point of the water in the conception test (please see ). All these forms of responses indicated that he had declarative knowledge and partially procedural knowledge on the cyclic nature of the water system.

### ***Relational Responsiveness***

Ahmet was one of the participants to explain relational responsiveness of the water system within the context of both living and nonliving subsystem's reactions. Reaction of living subsystems will be given under the section of "Causalities and Feedback Loops". The conversation of nonliving subsystem's reaction was given below.

Interviewer: ... Does water system react when a problem occurs? Why or why not?

Ahmet: It reacts, of course. For example, if the temperature increases, the evaporation in the seas will increase too. Then, more rain will occur to balance the level of water within the clouds. As a result, more floods appeared, and water will flow into the seas. So, the present water cycle will be accelerated.

Interview: So, I think the water system does not have brain. How does a nonliving thing decide what to do?

Ahmet: A nonliving thing react to something because of the physical laws. For instance, let's think about gravity. We are going to see that this pencil is going to fall when I throw up it.

The analysis of his responses revealed that he reflected his declarative and procedural knowledge on the relational responsiveness of the systems in water context. However, they were classified as partially correct since Ahmet failed to explain the nature of the complex organism's reactions to change in its environment.

### ***Properties of Water***

Ahmet mentioned physical changes of the water during the interview. While he was talking about polluted waters, he stated that

Polluted water evaporates too since polluted doesn't mean that they are exposed to chemical reaction...It is still water but in a gas state (conversation continues) ... When it evaporates, it purifies and continue cycling. The sediments remain on land.

The analysis of this excerpt revealed that he had correct both declarative and procedural knowledge on the physical changes of water during evaporation process.

### ***Water and Living Organisms***

Ahmet mentioned some interactions between the water and the living organisms, which are namely plant, animal, and specifically, the humanity. While he was explaining the mutual interactions between the living organisms and the water system, he stated that *“Plants and animals use the water for their survival purposes... (the conversation continues) ... However, people are an active agent in the water system since they use the water too much for agricultural and industrial purposes”*. The statement revealed that he had declarative knowledge that living organisms use water for their survival purposes. On the other hand, he did not elaborate the processes of survival functions. In terms of humanity, he explained that human is a factor that depletes water resources for the agriculture and industry which will be given in the subsequent sections. Overall, he had fully correct declarative knowledge and partially correct procedural knowledge statements on the interactions between the water and the living organisms.

#### **5.3.3.1.2 Power Sources of Water Cycle**

Ahmet indicated two of the power sources as sun and gravity. He failed to mention wind as a power source. During the interview as well as his drawing, no power source was indicated. Instead, he mentioned secondary sources as *“Heat and temperature differences as well as differential pressures leads to the movement of water. If temperature increases, then the water evaporates. When water vapor meets something cold, then it condenses, and it goes like this.”* Nevertheless, he failed to name the source of these temperature and pressure differences as sun.

In the conception test, Ahmet responded three questions related to the power sources. Unlike his drawing and the responses during the interview, he selected correct answers in the conception test (please see ). To sum up, he chose the best alternatives in conception test. However, he failed to include them during the other forms of data sources. Still, the data revealed that he chose sun and gravity as two of the power sources and partially revealed his procedural knowledge.

#### **5.3.3.1.3 Components and Processes in Water System**

Within the context of the components of water system, Ahmet mentioned 20 of 31 components in the conception test, his drawings as well as during the interview. In the conception test, he identified ocean as the biggest sources of water on Earth. In his drawing (Figure 5.23), he used the components such as water, sea, lake, clouds, and river. On the other hand, he mentioned animals, plants, sun, water vapor, stream, glaciers, spring, soil, creek, puddle, mountain, rain, groundwater, and human during the interview in different occasions.

In terms of processes, he identified six processes of out 17. In his drawing (Figure 5.23), he indicated the processes of evaporation, condensation, surface flow, and precipitation. On the other hand, he mentioned melting and sublimation during the interview.

During the data collection, Ahmet reflected different components and processes in different data sources. For example, he did not include all the processes and components that he identified in the conception test within his drawing. In his interview, he exemplified other components and processes. Overall, he exemplified 20 components of water system during the interview. Additionally, he explained six processes of water system. In terms of procedural knowledge, he explained partially some of the processes in the water system. He elaborated the process of evaporation and condensation, while he mentioned briefly the remaining four processes.

#### **5.3.3.1.4 Interactions among the Earth Systems**

The analysis of Ahmet's responses indicated all different relationships among the Earth systems given in the codebook as (1) hydrosphere and atmosphere; (2) hydrosphere (continental) and hydrosphere (marine); (3) hydrosphere and anthroposphere; (4) hydrosphere and geosphere; (5) hydrosphere and biosphere; (6) water cycle-nitrogen cycle; (7) water cycle-oxygen cycle; and (8) water cycle- carbon

cycle. Besides these categories, he also mentioned some of them through triple combinations and more. Each code and their combinations were given below.

The analysis of his drawing, interview, and responses of the conception test had some indicators about his understanding of the relationship between hydrosphere and atmosphere. In his drawing, Ahmet indicated evaporation, condensation, clouds, and precipitation. In terms of cloud formation, he explained it in the interview as “*They are general forms of water vapor. We can say that they are the visible versions of water vapor. But I don’t know about cloud formation*”. His statements revealed that he had naïve understanding on how clouds are formed. He had partially correct declarative knowledge for the clouds. Similar with his explanation, he had vague responses for the clouds in the conception test. For the first question, he failed to choose correct set of alternatives but for the other question, he selected the correct set of alternatives (please see ). This inconsistency indicated that he had naïve understanding on how clouds form.

The relationship between hydrosphere (continental) and hydrosphere (marine) was detected in his drawing and interview. [Figure 5.23](#) revealed that precipitated water flows to the sea. Similar with his drawing, he explained the water cycle as “*Water flows to the sea or lakes via rivers and creeks*” The analysis of his drawing and responses revealed that he had partial declarative and procedural knowledge on this relationship.

The relationship between hydrosphere and anthroposphere in detail during different instances in his interview. Overall, the analysis of his responses revealed that he had declarative knowledge on the interaction between hydrosphere-anthroposphere. In terms of procedural knowledge, he mentioned processes in detail between hydrosphere and anthroposphere even though he had some in-situ answers during the interview. The detail will be given in CUSL section.

The relationship between hydrosphere and geosphere emerged from the analysis of the interview. Ahmet mentioned this interaction in two instances. First, he stated that some

water resources spring from the inside of the mountains in some areas. On the other hand, he mentioned that water was used for irrigational purposes in the agricultural areas. These two examples revealed his declarative knowledge on the interaction between hydrosphere, anthroposphere and geosphere.

Combination of the five (sub)systems (water cycle-nitrogen cycle-carbon cycle-oxygen cycle- biosphere) was emerged from the analysis, when I asked, “*Is there any other system hidden in your drawing that might have an interaction with the water system?*” His sample excerpt was as following:

It was taught to us that there is a nitrogen cycle occurred by legumes. In order to achieve this, these plants need water from the rivers and the rains to survive.

*... (the conversation continues after the excerpt) ...*

One another thing is carbon dioxide. People, trees, and the animals emit the carbon dioxide. To survive, these living organisms need water and also oxygen. So, it affects indirectly.

The analysis of this excerpt revealed that he reflected his declarative knowledge (e.g., survival needs) on the relationship among these (sub)systems. However, he did not give detail about the procedures occurred among them.

Apart from the interactions among the natural cycles, he also mentioned briefly the relationship between hydrosphere and biosphere. He stated that plants and animals are only the user in the water system in a way that they only use water to survive.

In brief, when we examine [Figure 5.23](#) as well as his responses in different data collection instruments, we can summarize his functional systems literacy in [Table 5-12](#).

#### **5.3.3.1.5 Mapping the Interactions of the Categories in Ahmet’s Functional Systems Literacy**

[Figure 5.24](#) revealed the map was given below. The details of the mapping were given under the methodology chapter. Based on the content analysis of this section, I can summarize Ahmet’s functional systems literacy in water context as following:

- [Table 5-12](#) revealed that Ahmet had mostly declarative knowledge on the basic mechanisms of the water system. In terms of procedural knowledge, he had relatively good understanding on the working principles of the water system.
- No misconception had detected.
- *Components of Water System* had most interactive categories among the others. In other words, while Ahmet was talking about the basics of water system, he mostly used processes and components of the water system.
- *Power Sources of the Water Cycle*, on the other hand, was the most limited category among the others. There was a limited number of integrations into the other categories of FSL to explain the basics of the water system.

**Table 5-12**

*Summary of Ahmet's Functional Systems Literacy in Water Context*

| Categories / Codes *                               | Declarative<br>/Procedural | Fully<br>Correct<br>Statement(s) | Partially<br>Correct<br>Statement(s) | Incorrect<br>Statement(s) |              |
|----------------------------------------------------|----------------------------|----------------------------------|--------------------------------------|---------------------------|--------------|
|                                                    |                            |                                  |                                      | Consistent                | Inconsistent |
| General Characteristics of Water                   |                            |                                  |                                      |                           |              |
| Quantity of Water                                  |                            |                                  |                                      |                           |              |
| 1. Proportion of water resources                   | Declarative                | ✓                                |                                      |                           |              |
| 2. Change in amount of water on Earth              | Procedural                 | ✓                                |                                      |                           |              |
| Cyclic nature                                      | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Water and Living Organisms                         | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Relational Responsiveness                          | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 | ✓                                |                                      |                           |              |
| Properties of Water                                | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 | ✓                                |                                      |                           |              |
| Power Sources of Water Cycle<br>(2 out of 3)       | Declarative                |                                  | ✓                                    |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Components of the Water System<br>(20 out of 31)   | Declarative                |                                  | ✓                                    |                           |              |
| Processes of the Water System<br>(6 out of 17)     | Declarative                |                                  | ✓                                    |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Relationship between the Earth System (7 out of 8) |                            |                                  |                                      |                           |              |
| Hydrosphere – Atmosphere                           | Declarative                |                                  | ✓                                    |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Hydrosphere – Biosphere                            | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Hydrosphere – Anthroposphere**                     | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           | ✓            |
| Hydrosphere (continental)—hydrosphere (marine)     | Declarative                | ✓                                |                                      |                           |              |
|                                                    | Procedural                 |                                  | ✓                                    |                           |              |
| Hydrosphere - Geosphere                            | Declarative                | ✓                                |                                      |                           |              |
| Water cycle- Nitrogen cycle                        | Declarative                | ✓                                |                                      |                           |              |
| Water cycle- Oxygen cycle                          | Declarative                | ✓                                |                                      |                           |              |
| Water cycle- Carbon cycle                          | Declarative                | ✓                                |                                      |                           |              |
| TOTAL (n)                                          |                            | 15                               | 12                                   | 0                         | 1            |
| (D: Declarative, P: Procedural)                    |                            | (12 D, 3P)                       | (4 D, 8 P)                           |                           | (1 P)        |

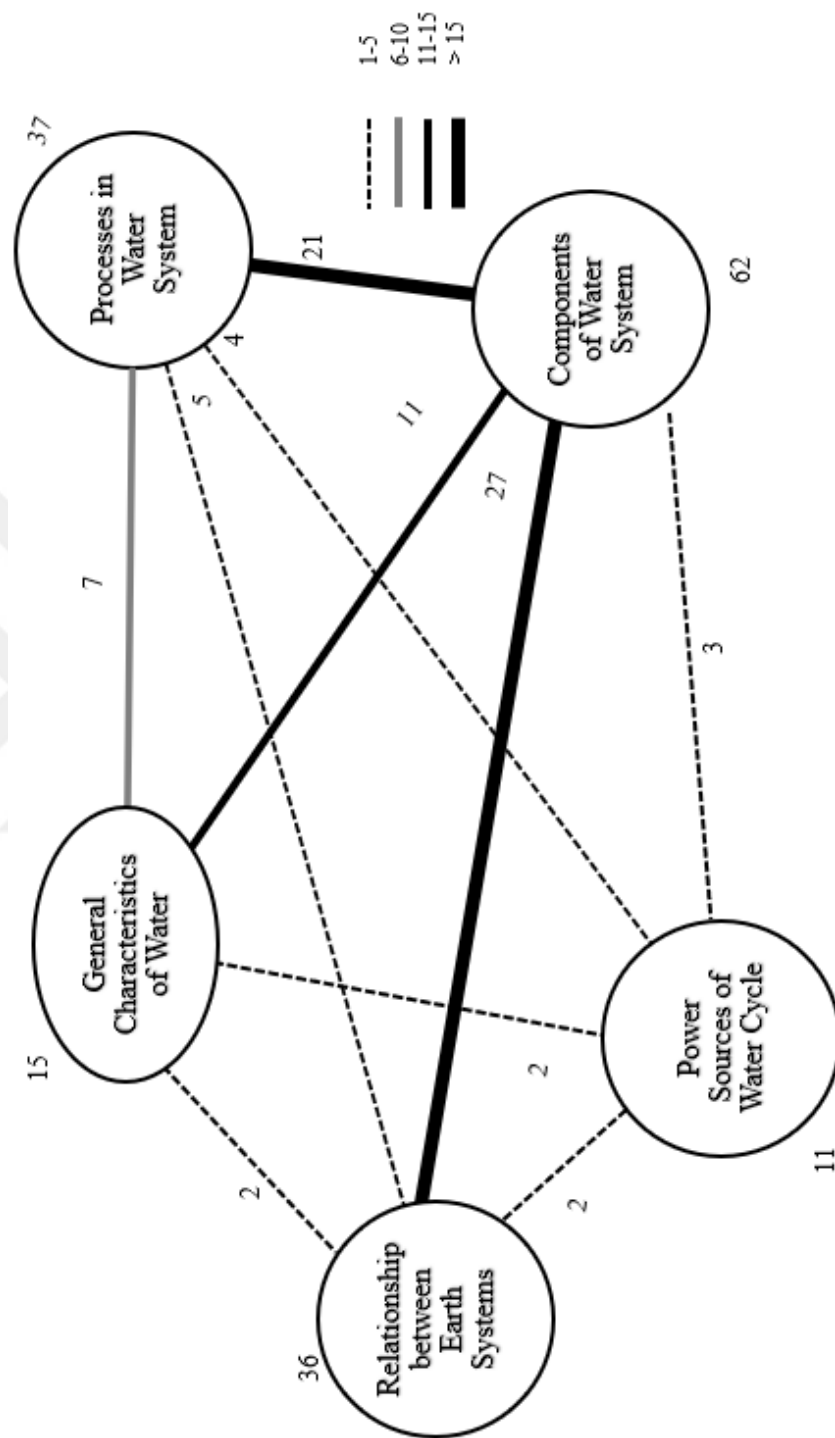
\* Not all categories/codes were given in this table since some of them were not observed in all participants

\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception.



**Figure 5.24**

*Mapping the Interactions among the Categories of Ahmet's Functional Systems Literacy*



### 5.3.3.2 Ahmet's Cultural Systems Literacy

Ahmet 's CUSL traced through the second drawing task and phase 2 interview questions. The categories and codes related to the basics of LWS was given in [Table 5-13](#).

#### 5.3.3.2.1 Components of Local Water System

Components of LWS was examined through the second drawing task as well as phase 2 interview questions. Within the context of the second drawing task, the researcher asked Ahmet to draw his local water system. However, his drawing was dominated by domestic water use. His notion related to the other components of water system, on the other hand, were traced during the interview. His second drawing was given in [Figure 5.25](#). His drawing included items of WSN and sewerage system. During the interview, he also mentioned animals, plants, human beings, and a local water resource as components of LWS. WSN and LWR will be given under the subsequent section.

#### *Local Water Resources*

In terms of specific names and functions of LWR, Ahmet named Aegean Sea as the only local water resource in his hometown. He added that there are some creeks and rivers coming from deep in the mountain in his hometown. However, he stated that he does not know names of them. Additionally, he identified a local water resource, a groundwater, from his village. He stated that as following:

There was an old plane tree at the village that was a symbol of there. There were some fountains around this plane tree and many people filled their water cans and used water for different purposes...I think this water is stored within the mountain and then flow with the gravity and reach to us.

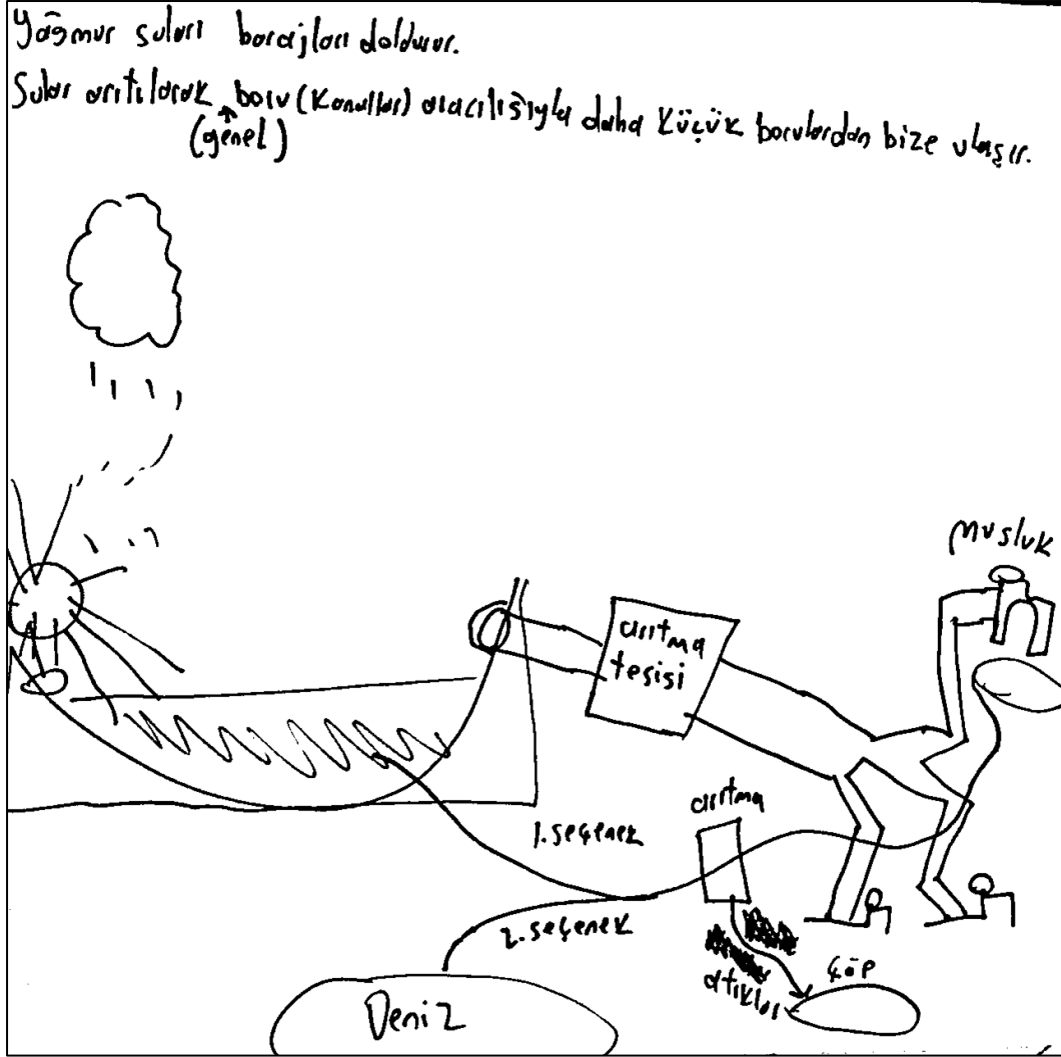
In terms of functions of LWR, he explained functions as survival, domestic, recreational, economic, energy source, and industrial. His statements related to these functions will be given in the next sections. Overall, Ahmet named one of the LWRs in his hometown. In terms of the functions of LWR, he explained six different functions for LWRs.

**Table 5-13***Categories and Codes – Ahmet’s Cultural Literacy*

| Theme: Basics of Local Water System (LWS)                               |                |                       |                                |                      |  |
|-------------------------------------------------------------------------|----------------|-----------------------|--------------------------------|----------------------|--|
| Category 1: Components of LWS                                           |                |                       |                                |                      |  |
| Animal                                                                  | Human being    | Local Water Resources | Sewerage System                |                      |  |
| Plant                                                                   | Microorganisms | Water Supply Network  |                                |                      |  |
| Sub-Category 1.1: Local Water Resources                                 |                |                       |                                |                      |  |
| Sub-Category 1.1.1: Name of LWR                                         |                |                       |                                |                      |  |
| Lake Tuz                                                                | Lake Eymir     | Çubuk Dam             | River Kızılırmak               |                      |  |
| Lake Mogan                                                              | Kurtboğazı Dam | Aegean Sea            |                                |                      |  |
| Sub-Category 1.1.2: Functions of LWR                                    |                |                       |                                |                      |  |
| Survival                                                                | Recreational   | Energy source         | Industrial                     |                      |  |
| Domestic                                                                | Economical     | Religious             | Agricultural                   |                      |  |
| Sub-Category 1.2: Water Supply Network (WSN)                            |                |                       |                                |                      |  |
| Sub-Category 1.2.1: Components in WSN                                   |                |                       |                                |                      |  |
| River                                                                   | Hail           | Pipe                  | Drinking Water Treatment Plant |                      |  |
| Cloud                                                                   | Water Puddle   | Engineers             | Water Storage Facilities       |                      |  |
| Freshwater                                                              | Well           | Water ATM             | Fountain                       |                      |  |
| Rain                                                                    | Dam            | Home                  | Groundwater                    |                      |  |
| Snow                                                                    | Lake           | People                | Sea                            |                      |  |
| Sub-Category 1.2.2: Processes in WSN                                    |                |                       |                                |                      |  |
| Precipitation                                                           |                | Water Distribution    |                                |                      |  |
| Water Accumulation                                                      |                | Water Treatment       |                                |                      |  |
| Sub-Category 1.3: Sewerage System                                       |                |                       |                                |                      |  |
| Sub-Category 1.3.1: Components in Sewerage System                       |                |                       |                                |                      |  |
| Pipe                                                                    |                | Receiving Environment |                                |                      |  |
| Wastewater Treatment Plant                                              |                |                       |                                |                      |  |
| Sub-Category 1.3.2: Processes in Sewerage System                        |                |                       |                                |                      |  |
| Wastewater Collection                                                   |                | Wastewater Treatment  |                                |                      |  |
| Category 2: National Water Resources (NWR)                              |                |                       |                                |                      |  |
| Sub-Category 2.1: Current State of NWR                                  |                |                       |                                |                      |  |
| Water Resources Potential                                               |                | Water Pollution       |                                |                      |  |
| Sub-Category 2.2: Name of NWR                                           |                |                       |                                |                      |  |
| Aegean Sea                                                              |                | Mediterranean Sea     | Lake Van                       | Uzungöl              |  |
| Black Sea                                                               |                | Marmara Sea           | Lake Dipsiz                    | Lake Tuz             |  |
| Category 3: Relationship among Local, National, and Global (Sub)systems |                |                       |                                |                      |  |
| LWS- WSN                                                                |                | LWS -Biosphere        |                                | LWS -Atmosphere      |  |
| LWS -Hydrosphere                                                        |                | LWS -Geosphere        |                                | LWS - Anthroposphere |  |

Figure 5.25

Ahmet's Local Water System



Water Supply Network and Sewerage System

During the second drawing task, Ahmet explained where water coming from to her home as following:

Rainwater is accumulated in the dams and then this is distributed via big pipes after the treatment. Small pipes, on the other hand, come to our house to provide water. I do not know how to construct a dam, but its baseline is so thick to accumulate water. Water may come from rain or treated wastewater. I do not know whether there is a

water treatment plant in my hometown, but I am sure that there is one treatment plant in the Aegean Region.

The analysis of his responses indicated that Ahmet identified eight components of WSN in his hometown. On the other hand, Ahmet explained the discharging process of wastewater as:

It goes to the creeks or seas from the basins. Or it could be discharged to another dam to retreat and reuse it again. (*he thought a minute*) ... I think they are treated in a treatment plant and then discharged to the sea. So, there could be two options (*he drew these options*)

The analysis of his responses revealed that Ahmet identified three components of sewerage system. However, he had limited amount of procedural knowledge about the WSN and sewerage system at his hometown. He stated that dams were filled by precipitation which was partially true. He failed to include freshwater resources to provide water in dams. On the other hand, he guessed that there would be one treatment plant in the Aegean region and reckoned that his hometown might not have one which was wrong. His hometown had more than one drinking water treatment plant. In terms of processes, he identified the water accumulation, water distribution, and water treatments for both drinking water and wastewater. No detailed explanation was given in terms of processes of the mechanisms of treatment plants. In short, Ahmet had declarative knowledge about the water systems at his hometown. However, he had naïve understanding in terms of the processes.

#### **5.3.3.2.2 National Water Resources**

The responses related to national water resources (NWR) were classified into two categories as *Name of NWR* and *Current State of NWR*. Ahmet mentioned that Turkey is a land surrounded on three sides by the sea and it also has two big lakes. He specified these names of NWR as Aegean Sea, Mediterranean Sea, Black Sea, Lake Van and Lake Tuz. In terms of current state of NWR, Ahmet claimed that Turkey is not one of the water rich countries in the world. He explained his reasoning as following:

We should have been one of those water rich countries since we have more precipitation area than some other countries, we have three seas, and two big lakes.

We could treat salty water and then use it for drinking purposes. I searched about it and it was very expensive. We due to climate change and misuse of water, we have become a country faced with water scarcity.

The analysis of his responses revealed that Ahmet claimed that Turkey is not one of the water rich countries in the world. He referenced his knowledge based on his personal research.

#### **5.3.3.2.3 Relationship between Local and Global (Sub)systems**

The analysis of Ahmet's responses emerged five different relationship among local and global (sub)systems as (1) LWS-Hydrosphere, (2) LWS-Atmosphere, (3) LWS-Anthroposphere; (4) LWS- Biosphere; and (5) LWS-Geosphere perspectives. Some of these relationships were mentioned by him through triple combinations and more. Each combination was given below.

As I outlined in the functional systems literacy section, he responded that the total amount of water is almost constant on Earth. Similar with his FSL, he stated that we use the same water repeatedly after treating the wastewaters, when he was talking about what happens to the domestic wastewater This statement reflected his declarative and procedural knowledge on the interactions between LWS and Hydrosphere in his hometown. On the other hand, he stated that dams were filled by rain. Even though this was partially correct, this statement reflected his declarative knowledge related to LWS and atmosphere.

During the interview, the relationships among the LWS, Biosphere and Anthroposphere were also mentioned by Ahmet as following:

There are living organisms in my hometown such as plants and animals, but they are not a significant element for the water system. On the other hand, people have multiple interactions with the water system. Ordinary people go fishing or swimming in the sea. Even though they are fishing for fun, some other people make money from it. Some people go fishing on the lake with their own small boats and sell them. Besides, there are some people too who perform sea trade.

His response indicated his declarative knowledge on the relationship among the LWS, biosphere and Anthroposphere. He revealed partially his procedural knowledge for those interactions.

In terms of the relationship between LWS and Geosphere, he stated that there are some creeks and rivers coming from deep in the mountain in the village that he visits during holidays which were given in the previous section. That sample excerpt revealed his declarative knowledge on this relationship.

In brief, when we examine [Figure 5.25](#) as well as his responses in different data collection instruments, we can summarize his cultural systems literacy as given in [Table 5-14](#).

#### **5.3.3.2.4 Mapping the Interactions of the Categories in Ahmet's Cultural Systems Literacy**

To explore the interactions among the categories in CUSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.26](#) revealed the map.

Cultural systems literacy of Ahmet in terms of local water system can be summarized based on the content analysis of this section as following:

- [Table 5-14](#) revealed that Ahmet have mostly declarative knowledge on the basic mechanisms of her local water system.
- [Figure 5.26](#) revealed that *Components of Local Water System* and *Processes in WSN* had most interactive categories among the others. In other words, while Ahmet was talking about the basics of local water system, he mostly used these two categories.
- *Relationship between Global and Local (Sub)systems*, on the other hand, were the most limited categories among the others. He integrated it rarely into the other categories of CUSL to explain the basics of his local water system.

In the next section, Ahmet's critical systems literacy in water context will be given.

Table 5-14

| Categories / Codes*                                  | Declarative<br>Procedural | Fully<br>Correct<br>Statement(s) | Partially<br>Correct<br>Statement(s) | Incorrect  |              | Don't<br>Know |
|------------------------------------------------------|---------------------------|----------------------------------|--------------------------------------|------------|--------------|---------------|
|                                                      |                           |                                  |                                      | Consistent | Inconsistent |               |
| <b>Components of LWS</b>                             | Declarative               | ✓                                |                                      |            |              |               |
| <b>Local Water Resources</b>                         |                           |                                  |                                      |            |              |               |
| <b>Name of LWR</b>                                   | Declarative               |                                  | ✓                                    |            |              |               |
| <b>Functions of LWR**</b>                            | Declarative               |                                  | ✓                                    |            |              |               |
|                                                      | Procedural                | ✓                                |                                      |            |              |               |
| <b>Water Supply Network and Sewerage System</b>      |                           |                                  |                                      |            |              |               |
| <b>Components</b>                                    | Declarative               |                                  | ✓                                    |            |              |               |
| <b>Processes</b>                                     |                           |                                  |                                      |            |              |               |
| <b>Water Accumulation</b>                            | Declarative               | ✓                                |                                      |            |              |               |
|                                                      | Procedural                |                                  |                                      |            | ✓            |               |
| <b>Water Distribution</b>                            | Declarative               | ✓                                |                                      |            |              |               |
|                                                      | Procedural                |                                  | ✓                                    |            |              |               |
| <b>Drinking Water Treatment***</b>                   | Declarative               |                                  | ✓                                    |            | ✓            |               |
|                                                      | Procedural                |                                  |                                      |            |              | ✓             |
| <b>Wastewater Collection</b>                         | Declarative               |                                  |                                      |            | ✓            |               |
|                                                      | Procedural                |                                  |                                      |            |              | ✓             |
| <b>Wastewater Treatment</b>                          | Declarative               |                                  | ✓                                    |            |              |               |
|                                                      | Procedural                |                                  | ✓                                    |            |              |               |
| <b>National Water Resources</b>                      |                           |                                  |                                      |            |              |               |
| <b>Water Resources Potential</b>                     | Declarative               | ✓                                |                                      |            |              |               |
| <b>Relationship between Local and Global Systems</b> |                           |                                  |                                      |            |              |               |
| <b>LWS-Atmosphere</b>                                | Declarative               |                                  | ✓                                    |            | ✓            |               |
| <b>LWS - Hydrosphere</b>                             | Declarative               | ✓                                |                                      |            |              |               |
|                                                      | Procedural                | ✓                                |                                      |            |              |               |
| <b>LWS - Biosphere</b>                               | Declarative               | ✓                                |                                      |            |              |               |
|                                                      | Procedural                |                                  | ✓                                    |            |              |               |
| <b>LWS - Anthroposphere</b>                          | Declarative               | ✓                                |                                      |            |              |               |
|                                                      | Procedural                |                                  | ✓                                    |            |              |               |
| <b>LWS-Geosphere</b>                                 | Declarative               | ✓                                |                                      |            |              |               |
| <b>TOTAL (n)</b>                                     |                           | 10                               | 10                                   | 0          | 5            | 2             |
| <b>Declarative (D)</b>                               |                           | (8D, 2P)                         | (6D, 4P)                             |            | (3D, 2P)     | (2P)          |
| <b>Procedural (P)</b>                                |                           |                                  |                                      |            |              |               |

Summary of Ahmet's cultural systems literacy in water context

\* Not all categories/codes were given in this table since some of them were not observed in all participants

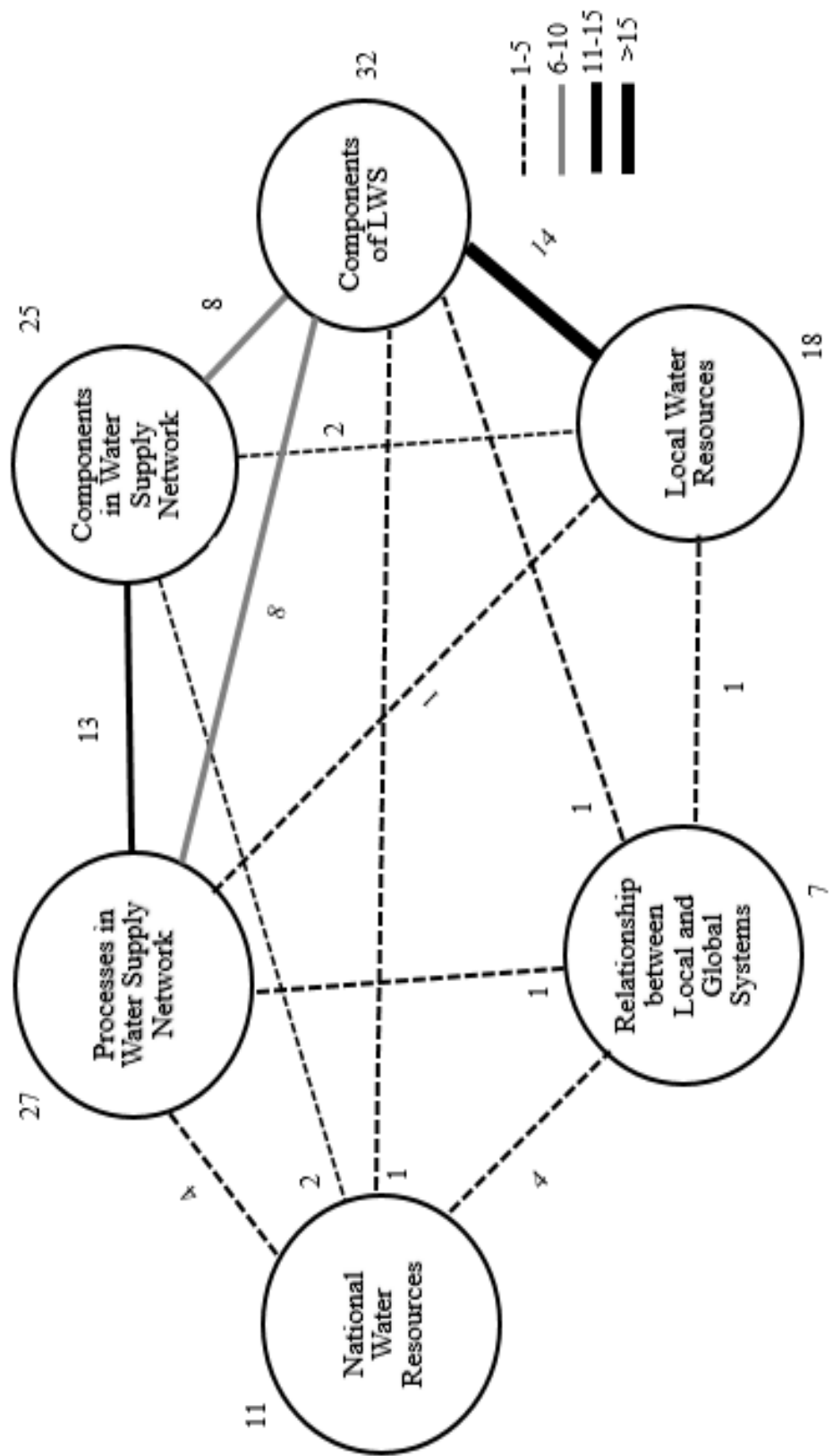
\*\* Even though participants have partially correct response in declarative knowledge, (s)he has fully correct response for the procedural knowledge.

\*\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception. OR they stated that they did not know the answer but tried to answer, though.



**Figure 5.26**

*Mapping the Interactions among the Categories of Ahmet's Cultural Systems Literacy*



### 5.3.3.3 Ahmet's Critical Systems Literacy

The findings in this section will be given under these two themes as well as their categories. Themes, categories, and codes of Ahmet's critical systems literacy in water context were summarized in [Table 5-15](#).

#### 5.3.3.3.1 Advance Mechanisms of Water System

The theme of advance mechanisms of water system were as following categories: dynamic nature of water system, causal dynamics and feedback loops, evolution of the system, and complexity of the water system. Each category was given in the subsequent sections.

##### 5.3.3.3.1.1 Dynamic Nature of Water System

As stated in the section of Quantity of Water, Ahmet was aware of that the total volume of the water is almost constant. Correspondingly, further questions were asked to portray his mental model on the unconscious use of water and its dynamic effect in the water system. Ahmet reflected his understanding on time delays and redistribution of the water in water system. The conversation was given below.

*... (the conversation continues before the excerpt) ...*

Interviewer: Ahmet, if the amount of water is constant, why are we concerning about the depletion of the water resources?

Ahmet: Even if the amount of water is relatively constant on Earth, the number of people is accelerating day by day. For example, we have 150 m<sup>3</sup> of water and it was enough for 100 people in 2000. In 2020, on the other hand, there would be 125 people, and this leads to decrease the amount of water per person. Besides, we pollute the water. Both overpopulation and water pollution lead to depletion of the water resources

Interviewer: So, what happens to that polluted water?

Ahmet: Polluted water is also one of the elements of the water cycle. Water evaporates too from the polluted resources. After all, it is not exposed to a chemical reaction, it is still water. When it evaporates, it purifies, and the sediments remain on land.

**Table 5-15***Categories and Codes – Ahmet's Critical Literacy*

| Theme 1: Advance Mechanisms in Water System                         |                                         |                 |
|---------------------------------------------------------------------|-----------------------------------------|-----------------|
| Category 1.1: Dynamic Nature of Water System                        |                                         |                 |
| CRDN111: Time Delay                                                 | CRDN112: Redistribution of Water        |                 |
| Category 1.2: Causal Dynamics and Feedback Loops                    |                                         |                 |
| CRFL121: Simple Open Loop                                           | CRFL123: Balancing Loop                 |                 |
| CRFL122: Reinforcing Loop                                           | CRFL124: Open Loop with multiple causes |                 |
| Category 1.3: Evolution of Water System                             |                                         |                 |
| CREV131: Decaying                                                   | CREV133: Toward higher organization     |                 |
| CREV132: Steady state                                               |                                         |                 |
| Category 1.4: Complexity of Water System                            |                                         |                 |
| Sub-Category 1.4.1: Interruptions in the Water System               |                                         |                 |
| CRCO1411: Climate Change                                            | CRCO1412: Hidden Use of Water           |                 |
| Sub-Category 1.4.2: Layers of Complexities                          |                                         |                 |
| CRCO1421: Environmental                                             | CRCO1424: Health                        |                 |
| CRCO1422: Economic                                                  | CRCO1425: Educational                   |                 |
| CRCO1423: Social                                                    | CRCO1426: Governmental                  |                 |
| Theme 2: Invisible Elements of Human System                         |                                         |                 |
| Category 2.1: Beliefs on Water Use                                  |                                         |                 |
| CRBL211: Self-use of water                                          | CRBL213: Sources of Beliefs             |                 |
| CRBL212: Collective use of water                                    |                                         |                 |
| Category 2.2: Self-efficacy towards Efficient Water Use             |                                         |                 |
| CRSE221: High                                                       | CRSE222: Low                            |                 |
| Category 2.3: Motive Concern                                        |                                         |                 |
| CRMC231: Social Altruistic                                          | CRMC233: Biospheric                     |                 |
| CRMC232: Egoistic                                                   |                                         |                 |
| Category 2.4: Action Strategies for Efficient Water Use             |                                         |                 |
| CRAC241: Persuasion                                                 | CRAC244: Reuse of water                 |                 |
| CRAC242: Water loss prevention                                      | CRAC245: Recycle of water               |                 |
| CRAC243: Reduce of water use                                        | CRAC246: No action                      |                 |
| Category 2.5: Emotional response                                    |                                         |                 |
| CREM251: Anger                                                      | CREM253: Happiness                      | CREM255: Apathy |
| CREM252: Sadness                                                    | CREM254: Proud                          |                 |
| Category 2.6: Motivational Orientation for Sustainable Use of Water |                                         |                 |
| CRMO261: Intrinsic motivation                                       | Amotivation                             |                 |
| CRMO262: Extrinsic motivation                                       |                                         |                 |

The analysis revealed that Ahmet was aware on the time delays in the water system. He attributed time delays to the water pollution and overpopulation. He claimed that as time passes (*20 years in his example*), the number of people will increase, and available water would not be enough for much more people. However, he failed to elaborate the dynamical mismatches because of the time delays.

Ahmet mentioned redistribution of water in the water system when he was talking about the effects of unconscious use of water on the water system as following:

Interviewer: ... So, how does our unconscious use affect the water system?

Ahmet: I have never thought this before... Let me formulate an idea about it (*he thought a minute*) ... The large part of the rainwaters goes into the streams and seas, while the remaining part goes into dams for human use. If people did use water from the dams much more than they need, more water will be discharged to the sea. This leads to an increase in the amount of evaporation, clouds are loaded too much, and finally more precipitation would occur. As a result, we could experience floods. Overall, unconscious use of water accompanying with climate change (*he has given the details of the mechanism of climate change in another part*) result in such events.

The analysis of his responses revealed that he explained redistribution of the water based on the effects of unconscious use of water and climate change. Overall, content analysis of his responses indicated that he was aware of the time delays and redistribution of water in the water system. He emphasized that both unconscious use of water and climate change affect redistribution pattern of the water in water system.

#### **5.3.3.3.1.2 Causal Dynamics and Feedback Loops**

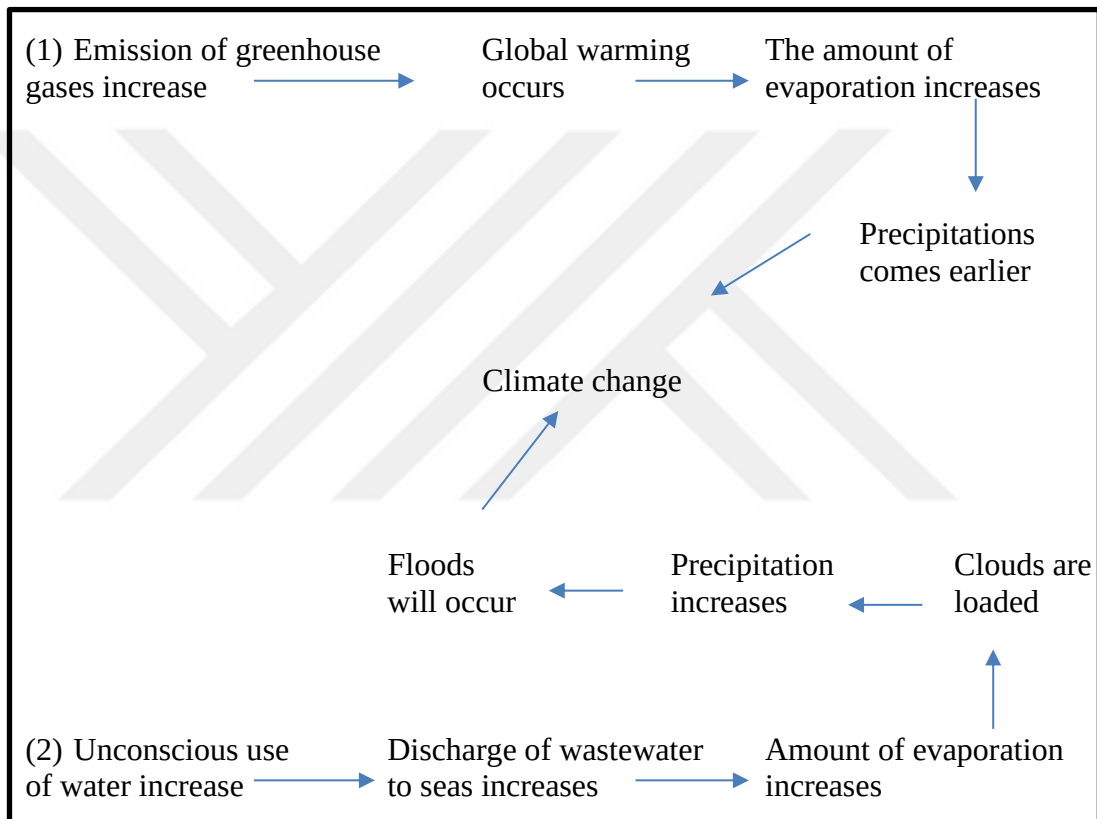
The analysis of Ahmet's responses indicated two open loops with multiple causalities, and two balancing loops. One of the open loops with multiple causalities was detected while Ahmet was talking about two different instances. First instance was about complexity of the water system in terms of climate change. He stated that:

Greenhouse effect leads to temperature anomalies during the seasons. This anomaly increases the amount of evaporation from the seas and the other water resources. As the evaporation occurs in a relatively short time interval compared to its average value, precipitations come earlier than they used to be. Then, climate change will be the result of climate change".

In another instance, while he was talking about the effects of unconscious use of water, he emphasized climate change. The sample excerpt was given under the section of “*Dynamic Nature of the Water System*”. The visualization was given in Figure 6.23.

**Figure 5.27**

*Ahmet’s Open Loop with Multiple Causalities in Climate Change*



The second open loop with multiple causes was observed in his responses related to the effects of the water system on people. Ahmet mentioned how people will be affected because of the several failures in the water system. Some was reported under the section of “*Complexity of the Water System*”. Another unreported excerpt was given below.

Some chain events occur when a failure is observed in the water system. At first, agriculture will be affected negatively, the crops will wither. Correspondingly, the consumer’s health will be affected negatively since they will not be able to get enough

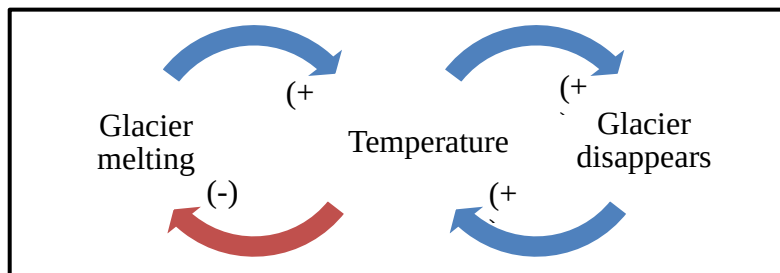
nutrients from the crops. On the other hand, water scarcity will be experienced, and this leads to some governmental problems. Governments will try to solve this problem, but the water level in dams will be much lower than before. Besides, water in the dams may be used for agriculture but this also creates a problem for the citizens' domestic use of water. Additionally, water scarcity would influence the animals' life badly. They would die because of it.

Based on this sample excerpt, open loop with multiple causalities was visualized in [Figure 5.29](#).

In terms of feedback loops, Ahmet explained implicitly one simple balancing loop and one combination of reinforcing and balancing loop. While he was talking about the effects of global warming and a simulation about what happens when temperature increases. His responses related to the effects of global warming was as following: *“Greenhouse leads to global warming. This warming will melt the glaciers. This melting rebalances the temperature because of its cooling effect. But at the same time, the factor that cools the weather will disappear. This intensifies global warming”* This sample excerpt can be visualized in [Figure 5.28](#).

**Figure 5.28**

*Ahmet's Balancing and Reinforcing Loops of Global Warming*



In another instance, while he was talking about how water system would react to changes, he mentioned a balancing loop as *“...if the temperature increases, the evaporation in the seas will increase too. Then, more rain will occur to balance the level of water within the clouds...”* His full excerpt was given under the section of “Relational Responsiveness”. This excerpt was visualized in [Figure 5.30](#).

**Figure 5.29**

*Ahmet's Open Loop with Multiple Causalities*

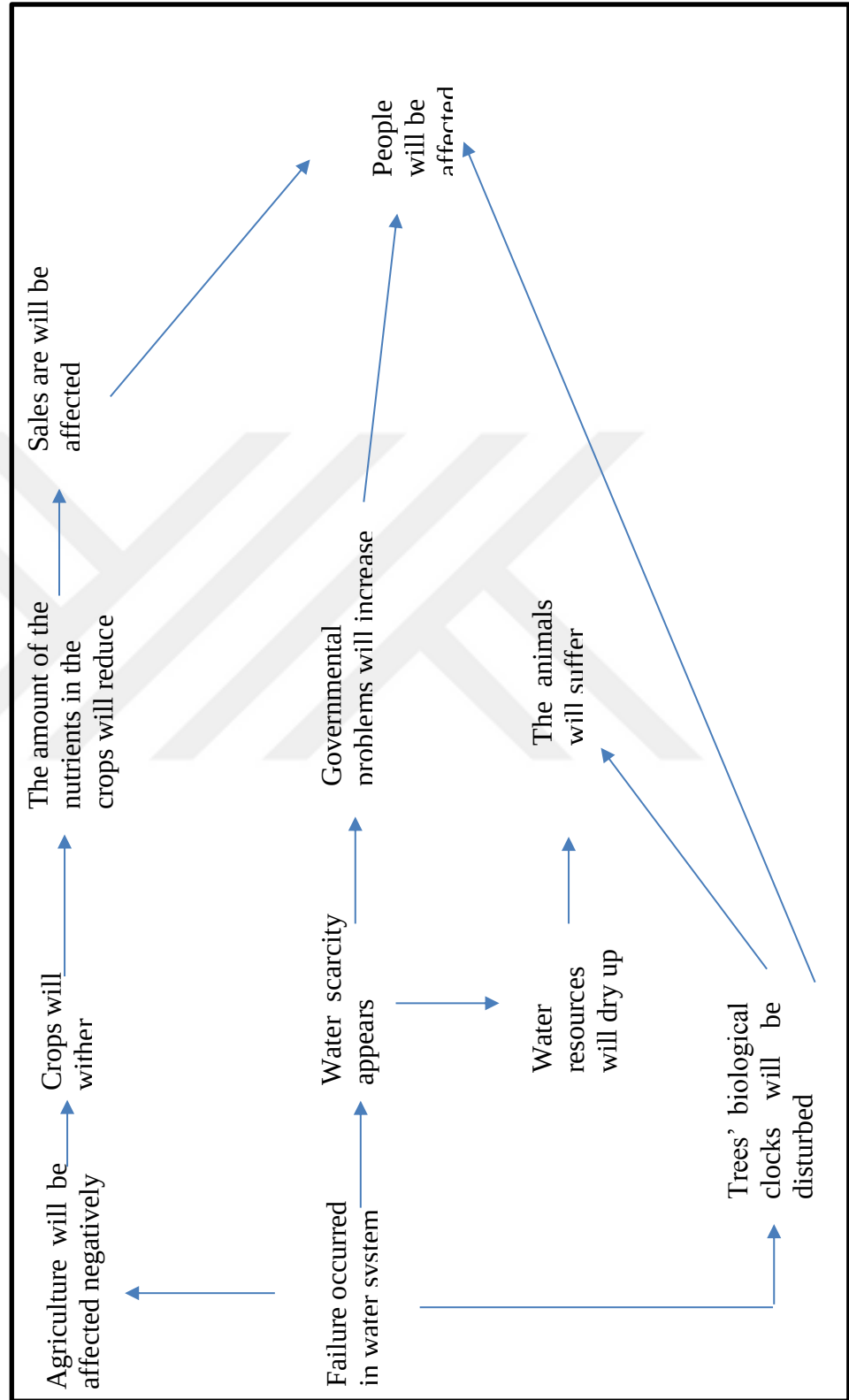
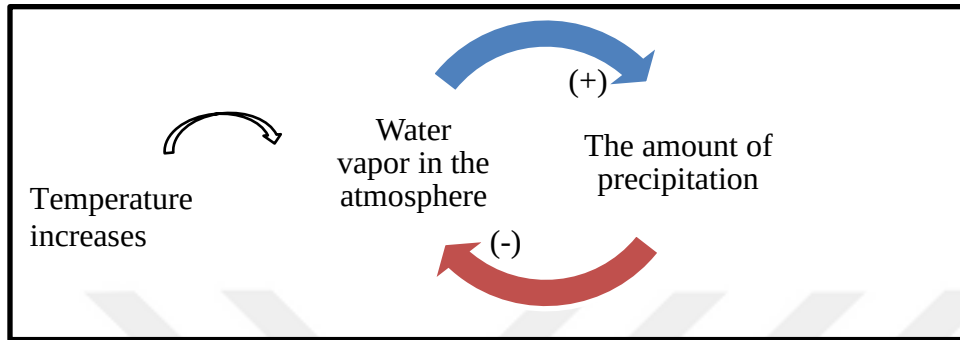


**Figure 5.30**

*Ahmet's Simple Balancing Loop*



Overall, Ahmet revealed his notion of causality in a system through two chain events in open loops with multiple causalities, one balancing loops, and one combination of reinforcing and balancing loop. While he was explaining his notion, he mainly attributed these causalities to the greenhouse effect, global warming, and climate change.

#### **5.3.3.3.1.3 Evolutionary Processes in Water System**

Ahmet addressed possible evolutionary scenarios for his local, national water system and the global water system. The sample excerpt for the national water system's evolutionary change was following:

If Turkey became wealthier and experienced a water-related problem, it would use its financial power fully to desalination processes. It would be same for my city too. However, this would be a bad scenario for Turkish people, the economy, and the nature. Our economy would be affected negatively. Moreover, the balance in the nature would be disturbed. If we desalinated the seawater, it means that our national water system would be in a bad situation and its amount would not be enough for all people. Thus, we should use seawater to compensate our needs. In a normal scenario, the Turkish government would increase the awareness of the citizens to decrease their water consumption. In this scenario, no change would occur in the water system.

Interviewer: I see. So, which option would occur in Turkey?

Ahmet: The former case. We would try first to desalinate seawater.



While he was talking about the future of her local water system, he made inference about the possible actions in the case of decaying state. Further, he claimed that this desalination process would disturb the balance of the nature. Overall, the analysis of his statements revealed that he interpreted the evolution of his local water system as decaying. However, he also predicted that Turkey would try to compensate this decaying by using its seawater which also leads to further problems. In terms of global aspects, he predicted different scenarios for different countries:

The global water system is bigger than our national water system. It is reported that overpopulation would be observed in Asian and African countries. Hence, the need for water in those countries would be higher than its present state. Maybe China would compensate this water scarcity issue due to its powerful economy, but it would not be the same for India, Bangladesh, Pakistan etc. They would be in worse situation than today's by means of water system. Every country would make provision against water scarcity. I saw on the news that United Arab Emirates was planning to carry iceberg from one of the poles to provide drinking water to the country.

The analysis of his responses revealed that he predicted that the evolutionary state of the global water system varies from one country to another. Some continents would experience water-related issues due to overpopulation, but he also added that some powerful countries would compensate this issue, while underdeveloped countries would suffer from water scarcity. In short, he claimed that there would be a decaying bot in globally and locally, but countries would react to make it steady state.

#### **5.3.3.3.1.4 Complexity of the Water System**

##### *Climate Change and The Water System*

The analysis of this part revealed that Ahmet could be able to detect interruptions in the water system and some of the layers of its complexity in this story. I asked to him “What happened to the water system in this story?” His rationale was following:

Ahmet: As the temperature increases, evaporation would also increase from the sea. Thus, more water vapor would go to the clouds. Emitting too much CO<sub>2</sub> gases to the atmosphere leads to the ozone layer depletion. Then, more sunlight comes into the Earth. More sunbeams are trapped in the atmosphere which is called greenhouse effect. Since the temperature increases due to greenhouse effect, glaciers are melting

to cool down the air temperature. However, glaciers are one of the factors that cool down the air temperature, but they disappear. Eventually, global warming occurs.

... *(the conversation continues after the excerpt)* ...

Interviewer: Okay, thank you. So, it was written that the seasons began earlier than expected. What could be the reason for it?

Ahmet: As I said earlier, it is due to the global warming. Fruits are ripening earlier since they are exposed to the heat that is required faster than ever because of the greenhouse effect... *(conversation continues)* ... To me, global warming is one of the results of the greenhouse effect. Climate change, on the other hand, is the result of the global warming.

Ahmet detected the failure of the water system within the case as climate change. He explained the mechanisms of greenhouse effect, global warming, and climate change, but he only failed to name it as manmade greenhouse effect. Besides, he revealed his misconception related to the global warming and ozone layer depletion. In terms of layers of complexities, he mentioned the effects of climate change on the environmental, economic, social perspectives. Sample excerpts were given below.

Farmers were directly affected because of the products. Trees were affected too since their biological clock was disturbed. Animals, which were fed by these trees, were affected. Then, consumers were affected since they should buy these products earlier. In a similar manner, logistic supervisors would be affected too... The efficiency rate gaining from the crops would decrease. For example, the amount of the nutrients that we gained from the crops such as vitamins and minerals will reduce, and this would be a health problem for us...

... *(the conversation continues after the excerpt)* ...

If I were a farmer on this village, I would be upset. However, I would also think about the possible solutions. For example, I would bargain with the truck driver to convince him to come earlier and buy my crops. I would think financially.

In short, Ahmet was able to identify the failure of the water system as climate change and explain its mechanism in detail based on the greenhouse effect and global warming. Moreover, he identified three different layers of complexity as economic, social, health, and environmental perspectives.

### *Hidden Use of Water and The Water System*

When I asked Ahmet about the term “hidden use of water” during the interview, he said he heard this term in one of the YouTube videos. He defined the term as:

While direct use of water refers to the water spent in washing the dishes, laundry, or our hands and face, hidden use of water refers to the water spent in products while manufacturing such as clothes that we wear or foods that we eat. For example, the sausage includes meats coming from an animal and they consider the amount of water that the animal drink in its lifetime. We all have water footprints including these activities and products.

Consecutively, I asked to him whether he know the exact amount of water for producing 1 kg of sausage. He responded that “*I don’t remember but 2000 liters was spent for a cloth in the documentary called 25 liters. I saw it on the TV a few days ago.*” I asked Ahmet to explain water consumption in a hamburger. He responded as following:

Interviewer: What about, for instance, a hamburger? Do we spend water for it?

Ahmet: at first, water is spent during the bread production. Wheats are grown in the fields and irrigated. There must be huge consumption in there. Then, animal spends water for surviving but it may not be too much compared to others. Tomatoes and lettuce are also irrigated, so we should include their water consumption too. Maybe, some water could be spent during transportation.

Interviewer: So, do you remember how much water do a hamburger have in total?

Ahmet: No, but I know that it has more water than direct use of water.

Interviewer: OK, when you think about the process of hamburger production, who are responsible for the consumption of water?

Ahmet: The governments and the consumers. Consumers have lack of awareness on the hidden use of water and government do nothing about it.

The analysis of the conversation revealed that Ahmet had correct declarative knowledge about the term “hidden use of water”. However, when more elaborative questions were asked about water consumption in a product, for example, he had the ability to infer consumption of water at some level, but he failed to reveal his procedural knowledge about the water for animals’ grain, hamburger’s packaging process as well as wastewaters spent for the production. This indicated that he had procedural knowledge partially about the processes during the production. Besides, he stated that governments and consumers were responsible for the water consumption.

### 5.3.3.3.2 Invisible Elements of Human System

In this section, the findings were given within the categories of beliefs about water use, action strategies for efficient water use, emotional responses, motive concerns, and motivational orientation for sustainable water use. The category of self-efficacy beliefs towards efficient water use was not emerged in Ahmet's responses.

#### 5.3.3.3.2.1 Beliefs on Water Use

##### *Beliefs on Self-use of Water*

Self-use of water was traced in the interview part. The analysis of his responses indicated that Ahmet had inferential belief that "*I have no effect on the water system*". To understand the rationale of his belief, I asked to him in which activities does he consume water in a day. He stated that:

I am not seeing myself as an active agent on the water system. I do not have too much dirty plates after meal, take a shower in an average compared to other people. Neither I waste water too much, nor I use it sparingly. I think I am neutral.

... *(the conversation continues after the excerpt)* ...

I am a regular water user. I use it when I am taking shower, washing my hands and face, flushing the toilet, brushing my teeth. I turn off the taps while I am brushing my teeth. My hidden use of water in a day can be my food that I eat during the day and the bottle water that I buy...

Analysis of his responses revealed that he formed his beliefs based on daily experiences related to his direct use of water. He stated that he was a regular user who use the same amount of water compared to other people. As a result, he believed that he had no effect on the water system.

##### *Beliefs on Collective Use of Water*

In this part, the role of people in water system was asked to trace Ahmet's beliefs on collective use of water. In terms of the role of people in the water system, he had two inferential beliefs as "*Older people have negative effects on the water system*" and

*“Older people have more water consumption rate than me”*. He explained his inferences as following:

They have more water consumption rate than me. They wash their cars, for example. Additionally, they have more hidden use of water consumption since they have more clothes than me. Moreover, they travel more than me. This travel not only pollute the air but also affect the water resources. Thus, they have negative effects on the water system.

The analysis of this sample excerpt revealed that he formed his belief for the collective use of water from his observations. He mentioned that older people’s hidden use of water had negative effects on the water system, and he exemplified it based on his direct experiences. Besides, he compared his activities in terms of hidden use of water and inferred that older people have more water consumption rate.

#### **5.3.3.3.2.2 Action Strategies for Sustainable Water Use**

As Ahmet reported that he has heard about sustainability but not remember its scope in detail, the interview was built based on his action strategies of efficient water use. Correspondingly, I asked him to explain whether he set a goal related to sustainable water use in his daily life. His response was following:

Ahmet: I do not have a goal to use water efficiently because I am not such a person using water recklessly. I am not a water-saver person, either. I am just an ordinary citizen.

Interviewer: What about your hidden use of water? Do you set a goal for it?

Ahmet: No. I have never been careful about it. After seeing that video (referring the video of hidden use of water), however, I realized that I do not have so much hidden use of water. So, watching that video did not change my behavior.

*... (the conversation continues after the excerpt) ...*

The sample excerpt revealed that he had no action strategies for efficient water use. He reported that his water consumption was not too high, so no further action was needed to monitor it. In short, Ahmet had no action related to efficient water use both direct use and hidden use of water.

#### 5.3.3.3.2.3 Emotional Response

His emotions related to effects of people on the water system were asked. His response was following:

Ahmet: For example, they have dishwasher at their house, but they wash the dishes by hand before putting them into the dishwasher. The tap remains open while they are doing this. These are bad behaviors, but I do not need to react them. I do not have any emotional response

Interviewer: Could you please explain why you do not have emotional response for that bad behavior?

Ahmet: I do not know. Maybe, it is because I do not see any negative effect of that bad behavior directly. If the mayor of the town announces that, for instance, water supply will be cut off for three days due to unconscious use of water in the previous month, then a not only me but also the local people would react it. As we do not have direct responsibility, we do not feel responsible. Moreover, since I have not ever seen a negative effect of unconscious use of water in my life, I may lack an emotional response for it.

The analysis of his responses indicated that apathy was his emotional response. He explained the reason for being apathetic as having no direct experiences of the negative effects of unconscious use of water.

#### 5.3.3.3.2.4 Motive Concern

Motive concerns of the participants were examined by the interview questions. Correspondingly, the responses of the interview questions were analyzed to portray their motive concern. Even though Ahmet reported that he had no action strategies and no emotional response related to the water system, he revealed his motive concerns while he was talking about the importance of water system. The sample excerpt was given (please see [Figure 5.29](#)) under the section of “*Causalities and Feedback Loops*”.

While Ahmet shared his ideas about maintenance of water system, he emphasized all living organisms, who are possibly be affected from disruption in the water system. This response was an indicator of his biospheric motive concern. However, he emphasized mainly the importance of water system for people’s life in different

instances during the interview. This was an indicator of dominance of social altruistic motive concern.

During different instances in his interview, his social altruistic motive concern was dominant compared to biospheric motive concern. In short, Ahmet hold different motive concerns about the present state of water system, but social altruistic value orientation was dominant in his responses.

#### **5.3.3.3.2.5 Motivational Orientation**

As presented in the previous sections, Ahmet reported that he did not have specific goal for using water efficiently. He stated that he was an ordinary person who already did not use the water recklessly. In terms of motivational aspect, it was asked to Ahmet that the for not having specific goal to perform the action. His specific answer related to that question was following:

Interviewer: Why do not you have specific goal for using water efficiently?

Ahmet: As I said earlier, I am already a regular water-user who do not waste it because I believe that it is nonsense to open a tap and waste the water for nothing. Since I am already doing it, I do not have further motivation to use water efficiently.

Interviewer: What if you realized that you use it recklessly? Would you change your water consumption behavior?

Ahmet: No because everybody else would also use the same amount that I consume, so it would be our average consumption rate. I would change my water consumption behavior if and only if other people reduced their water use. If I saw my friend turned off the tap while he was brushing his teeth, I would also turn it off, for example.

The analysis of his responses indicated that he had *amotivation* towards regulation of his water consumption behavior. Amotivation refers to explain people's unwillingness to perform an action. Among the three types of amotivation, Ahmet's amotivation was classified as lack of competence because one believes that individual actions are not effective itself (Ryan & Deci, 2017). In a similar manner, if he was a person that uses water recklessly, then he would regulate his water use provided that everybody else changed their water consumption behavior.

#### 5.3.3.3.3 Summary of Ahmet's Critical Systems Literacy in Water Context

The analysis of Ahmet's critical systems literacy in water context were given in two themes. In terms of *advance mechanisms of water system*, Ahmet's explanations were categorized in four categories. In term of dynamic nature of water system, he reflected her declarative knowledge on time delays and redistribution of water in water system. However, he failed to elaborate the dynamical mismatches because of the time delays and formed his response for redistribution of the water. On the other hand, he exemplified causal dynamics by explaining them as two open loops with multiple causalities, and two balancing loops. While he was explaining his notion on the causalities, he mainly attributed these causalities to the greenhouse effect, global warming, and climate change. In terms of evolutionary processes in the system, he claimed that there would be a decaying bot in globally and locally, but countries would react to make it steady state. Last, Ahmet's reflections related to the real story and the concept of hidden use of water were indicators of his notion on the complexity of the water system. He detected climate change as a disruption in the water system and he mentioned three different layers of complexity as economic, social and environmental perspectives. In terms of hidden use of water, however, Ahmet had declarative knowledge correctly about the term "hidden use of water" but was able to infer some of the processes during the manufacturing of the products. Besides, he specified that the consumers and the governments were responsible for the water consumption since they bought it.

Under the theme of *invisible elements of human system*, Ahmet's responses were given by means of five categories. In terms of beliefs on water use, he reflected his beliefs on self-use and collective use of water. He gave detailed information about the sources of his beliefs. He had descriptive on his self-use of water as "*I have no effect on the water system*". While he was mentioning it, he gave his rationale from his direct experiences. In terms of the role of people in the water system, In terms of the role of people in the water system, he had a descriptive belief as "*Older people have negative effects on the water system*" and an inferential belief that "*Older people have more*



*water consumption rate than me*”. He formed these beliefs from direct experiences as well as his descriptive beliefs. Ahmet had no specific action strategies for efficient water use. He reported that his water consumption was not too high, so no further action was needed to monitor it. In a similar manner, apathy was detected in his emotional response. He explained the reason for being apathetic as having no direct experiences of the negative effects of unconscious use of water. Albeit Ahmet reported that he had no action strategies and no emotional response related to the water system, he indicated his motive concerns while he was talking about the importance of water system. Social altruistic and biospheric value orientations were observed and social altruistic was dominant motive concern. Last, similar with action strategies and emotional response, he had amotivation towards efficient water use. He stated that if he was a person that uses water recklessly, then he would regulate his water use provided that everybody else changed their water consumption behavior.

#### **5.3.3.4 Mapping the Interactions of the Categories in Systems Literacy**

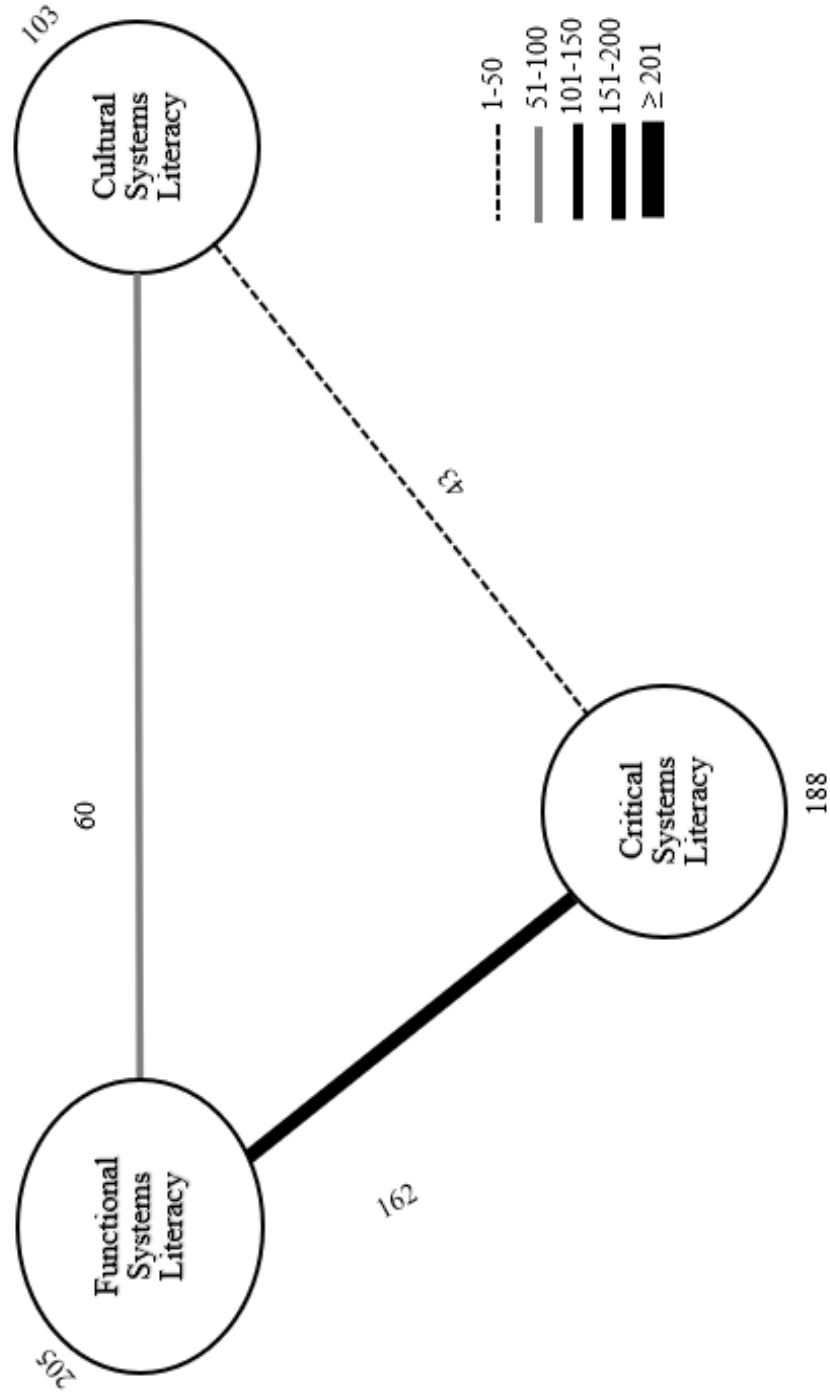
To explore the interactions among the FSL, CUSL, and CRSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. Figure 6.33 revealed the map. The order of the interactions from highest to the lowest among the elements of systems literacy was FSL-CRSL, FSL-CUSL, and CUSL-CRSL.

The interactions among the elements of systems literacy of Ahmet in terms of water system can be summarized based on the content analysis of this section as following:

- He had substantial amount of knowledge about the basic mechanisms of water system (FSL) compared to basics of his local water system (CUSL).
- [Figure 5.31](#) revealed that *Functional Systems literacy* had most interactive literacy element among the others, whereas *Cultural Systems Literacy* was least interactive.
- The number of interactions between *Functional Systems Literacy* and *Critical Systems Literacy* were higher than the other combinations of interactions (FSL – CUSL; CUSL-CRSL).

**Figure 5.31**

*Mapping the Interactions among Ahmet's Systems Literacy Elements in Water Context*



#### **5.3.4 Case 4: Deniz**

Deniz was born in 2005. She is a ninth-grader female student in a private high school located in an inland city. She reported that she was one of the high achievers in her school. Her school offers an extra class after the school for the high-achievers and she was one of them. Her high school entrance exam score was 390 points which corresponded to top %15 of the applicants in that year. Besides, she is a professional volleyball player in a sport club in her city.

Deniz's mother is an environmental educator working in a science museum; her father is a banker. Their house is located one of the most crowded towns in the capital city. There is no natural water resource such as lake and river around their house. In terms of water context, she did not enroll any project, course, or seminars related to that context. Moreover, she has not special interest in this content. In terms of the concept of the sustainability, Deniz reported that she did not remember the context of sustainability. In the ninth grade before I collected data from her, properties of water such as evaporative cooling, adhesion and cohesion were taught in her biology class. In chemistry, on the other hand, the properties of water as a universal solvent and water as a polar molecule were given.

I worked with Deniz in two sessions. The responses of Deniz through the conception test, first drawing task, and interview questions reflected some indicators related her systems literacy. The analyses of her responses were given below under the sections of functional systems literacy, critical systems literacy, and cultural systems literacy.

##### **5.3.4.1 Deniz's Functional Systems Literacy**

The analysis of his responses in conception test, first drawing task and interview phase 1 revealed her functional systems literacy in five categories as (1) general characteristics of water; (2) power sources of water cycle; (3) components of water cycle; (4) processes of water cycle and (5) relationship between the Earth systems. [Table 5-16](#) indicated codes and categories for her functional systems literacy in water context.

**Table 5-16***Themes, Categories and Codes: Deniz's Functional Systems Literacy*

| Theme - Basics of Water System                                |                                     |
|---------------------------------------------------------------|-------------------------------------|
| <i>Category 1: General Characteristics of Water</i>           |                                     |
| FGC11: Quantity of Water *                                    | FGC14: Water and Living Organisms   |
| FGC12: Cyclic Nature                                          | FGC15: Relational Responsiveness**  |
| FGC13: Properties of Water                                    |                                     |
| <i>Category 2: Power Sources of Water Cycle</i>               |                                     |
| FPS21: Sun                                                    | FPS23: Gravity                      |
| FPS22: Wind                                                   |                                     |
| <i>Category 3: Components of Water System</i>                 |                                     |
| FC31: Plant                                                   | FC317: Cloud                        |
| FC32: Sun                                                     | FC318: Rain                         |
| FC33: Water                                                   | FC319: Snow                         |
| FC34: Animal                                                  | FC320: Fog                          |
| FC35: Human                                                   | FC321: Hail                         |
| FC36: Ocean                                                   | FC322: Freshwater                   |
| FC37: Sea                                                     | FC323: Ice                          |
| FC38: Water Vapor                                             | FC324: Well                         |
| FC39: River                                                   | FC325: Lake                         |
| FC310: Glacier                                                | FC326: Stream                       |
| FC311: Spring                                                 | FC327: Dew                          |
| FC312: Soil                                                   | FC328: Algae                        |
| FC313: Wetland                                                | FC329: Creek                        |
| FC314: Rock                                                   | FC330: Puddle                       |
| FC315: Groundwater                                            | FC331: Mountain                     |
| FC316: Aquifer                                                |                                     |
| <i>Category 4: Processes of Water System</i>                  |                                     |
| FP41: Evaporation                                             | FP410: Surface flow                 |
| FP42: Condensation                                            | FP411: Melting                      |
| FP43: Sublimation                                             | FP412: Freezing                     |
| FP44: Evapotranspiration                                      | FP413: Frosting                     |
| FP45: Respiration                                             | FP414: Dissolution                  |
| FP46: Precipitation                                           | FP415: Transpiration                |
| FP47: Penetration                                             | FP416: Capillarity                  |
| FP48: Infiltration                                            | FP417: Photosynthesis               |
| FP49: Underground flow                                        |                                     |
| <i>Category 5: Interactions among the Earth (Sub)Systems*</i> |                                     |
| FRES51: Hydrosphere—atmosphere                                | FRES55: Hydrosphere-anthroposphere  |
| FRES52: Hydrosphere—geosphere                                 | FRES56: Water cycle- nitrogen cycle |
| FRES53: Hydrosph. (continental)—hydrosph. (marine)            | FRES57: Water cycle- oxygen cycle   |
| FRES54: Hydrosphere—biosphere                                 | FRES58: Water cycle – carbon cycle  |

\*black codes: emerged from Deniz's responses

\*\*pale codes: not apparent in Deniz's responses

#### 5.3.4.1.1 General Characteristics of Water

The first category in explaining Deniz's functional systems literacy was general characteristics of water. Deniz's answers for the questions for this session were given by means of quantity of water, its cyclic nature, properties of water, and water and living organisms.

##### *Quantity of Water*

In the conception test, Deniz responded that most of the water on Earth is found in oceans, but she also wrote an additional note that: *"I think that there is also so much water stored as groundwater."* Her response revealed that she was not sure about the percentages of water in different resources. On the other hand, she revealed her misconception in the conception test that *"the amount of water on Earth increase and decrease in time"*. (please see ).

In the second session, on the other hand, while she was talking about human use of water, she again emphasized the change in the total amount of water on Earth. At this point, I asked to her *"where does water go when it decreases?"* Her response was:

I don't know how but water goes somewhere. Let's assume that we drink water. Where does the water go that I drink? It comes to my body, but what if I die? I would say it stays in my body but there is no such logic (*she laughed*). Of course, it goes somewhere... For example, where does water go when it evaporates? It goes into air, but I don't know if it goes away from the Earth or not. I don't think it occurs that way. We would use it again.

... (*the conversation continues after the excerpt*) ...

I think the amount of water on Earth decreases day by day but also at the same time, it may increase somewhere else by precipitation.

... (*the conversation continues after the excerpt*) ...

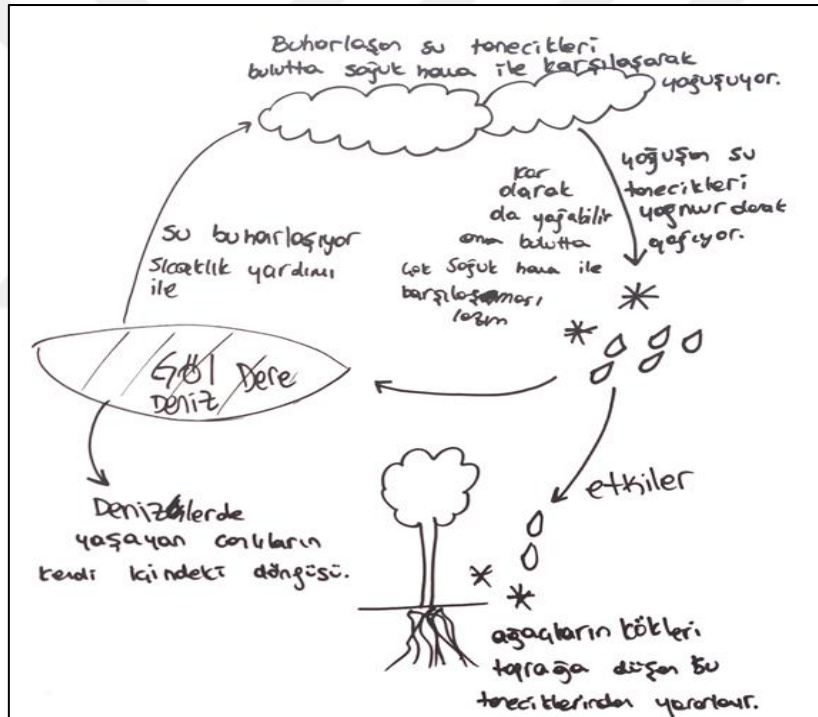
The analysis her answers in different forms of questions (conception test items, interview questions) revealed that she failed to sort the proportions of water in different water resources. Moreover, she failed to express that the amount of water is almost constant on Earth. Instead, Deniz had a misconception and it was consistent and stable in different context during data collection.

## Cyclic Nature

For acquiring information about her notion on the cyclic nature of water, the first drawing task was analyzed. In her drawing, she used arrows to show how water cycles. She indicated that rain or snow goes into either any water resource like lake, sea, or river or into land where tree uses it. Then, the water goes back into atmosphere thanks to the evaporation. The figure was given below.

Figure 5.32

Deniz's Drawing of Water Cycle



After the first drawing task ended, she explained how water cycle occurs as following:

Deniz: Water evaporates with the help of the heat and water vapor accumulates into the clouds and... when water vapor meets the cold air, it condenses. By the time they condense, their mass can't stay up in the air, so they precipitate to the earth's surface. It may precipitate as snow or rain. The air should be too cold for snow so that it could crystallize. After precipitation, water goes back again.

... (the conversation continues after the excerpt) ...

Water do not have to fall into water resources every time; it also precipitates to land. Moreover, it is used by trees via their roots.

One another point in her figure is that precipitation goes into soil and tree uses this water. However, the journey of water has ended in this figure. No specific item was drawn by Deniz about what happens to water after tree uses it. However, this part was elaborated by her in the latter part of the interview as “*The other plants can be also elements of water system by performing respiration and transpiration. They need the water of our local water system and, they also release water...When plants perform transpiration, this also contributes to the water cycle*”. The analysis of this response revealed that even though she did not complete the cycle in her drawing from the land, she was aware of water continues cycling after a tree used it. Still, she did not mention the mechanism of how water continue cycling after a tree release it.

During the interview, she elaborated the cyclic nature as following:

... Since its name is water cycle, it starts where water is available, and it also finishes within water because it returns to water due to its cycling property... There may be no starting and ending point... I mean it depends on where we look to the cycle but to me, it starts in a place where water accumulates such as lake... (*she wanted to think about it again*) ... It starts with water in liquid state and ends where water is again in liquid state...

In the latter parts of her interview, she again mentioned starting-ending point of water cycle in different contexts. For instance, while we were talking about “where does water go when we discharge it?” she stated that

... It doesn’t make any sense to me that the water that we use our homes could be used again... this may not be the case.

... (*the conversation continues after the excerpt*) ...

... I mean I washed a dirty, oily thing with a detergent in the kitchen... and the water comes back to us again?!...

... (*the conversation continues after the excerpt*) ...

From this sample excerpt, it can be observed that she had difficulties to imagine how water cycles again after we discharge the wastewater. In another case, while she was talking about the importance of the maintenance of water system, she stated that

... (the conversation continues before the excerpt) ...

... there was a question at the beginning whether there is a starting point of water cycle. I think, it has a starting point because unless there is no water accumulation or water resources, water cycle couldn't be start. But when it starts, it goes back where it starts which is water..."

... (the conversation continues after the excerpt) ...

In her responses, it can be examined that she had some difficulties while explaining the cyclic nature of the water. In the former case, she couldn't imagine the cyclic nature of water when she discharged the wastewater from her house. In the latter case, however, she claimed that water comes back to the place where it starts. She couldn't explain that cycles do not have starting/ending points.

Overall, her answers in different forms of questions (conception test items, drawing task, and interview questions), revealed that Deniz had declarative knowledge on the mechanisms of cyclic nature of water. She used the term "cycle" in different instances. Nonetheless, she had some difficulties to transfer her knowledge when she was talking about water use of humans as well as other living things. This might be an indicator of her lack of procedural knowledge on water cycles in different contexts.

### ***Properties of Water***

While Deniz was talking about the water system, she reflected her knowledge about some of the chemical properties of water. For example, while she was talking about cloud formation, she stated that "*Chemical bonds between the water molecules break down and they go up. What I'm trying to say is they start to go up to the atmosphere because their weight become lighter...*" She mentioned chemical bonds between water molecules while explaining the process of evaporation. However, she failed to state that intermolecular forces decrease in this phase change. Additionally, she also revealed her misconceptions about density concept such as "*heavier things sink*" which refers to a common confusion between density and weight. In short, she had naïve understanding about this specific physical property of water and had misconceptions in explaining the mechanisms.



### ***Water and Living Organisms***

Deniz mentioned some interactions between the water and the living organisms, which are namely plant, animal, and specifically, the humanity. For example, while she was explaining the importance of maintenance of water system, she stated that:

They (*referring all living organisms*) use water for maintaining their vital activities. For example, we would die if we didn't drink water. It's same for the other living organisms. Their homeostasis will disrupt if they didn't take enough water. After all, substantial amount of our body includes water.

The statement revealed that she had declarative knowledge on the importance of water in terms of homeostasis as well as its amount in living organisms. that living organisms use water for their survival purposes. On the other hand, she elaborated the processes of survival functions such as transpiration and photosynthesis which will be given in the subsequent sections. In terms of humanity, she explained that human is a factor that depletes water resources for different purposes. Overall, she had declarative knowledge on the interactions between the water and the living organisms. In terms of procedural knowledge, she explained the processes in detail which will be given in the subsequent sections.

#### **5.3.4.1.2 Power Sources of Water Cycle**

Deniz stated all the three power sources in different data sources She used no power source while drawing water cycle. On the other hand, she mentioned sun, wind, and gravity during her interview. She explained the power sources of water cycle in her drawing as following:

It goes up thanks to the hotness. The temperature is the power source, I think. When it precipitates, their own mass couldn't fit the clouds anymore and then they fall... (*conversation continues*) ... It couldn't stay in the clouds because it becomes heavier for a cloud. When it goes up (*she meant evaporation*), it is not a problem because it is light. But when it condenses, it combines with other water droplets which makes it heavier and it falls to the Earth's surface.

Her explanation revealed that she implicitly was talking about the sun and gravity but failed to name these power sources. In the latter part of the interview, she was talking

about the wind and its functions as “...Then, clouds are pushed by the wind and it may lead to another rain...”. Similar with the former case, she failed to name wind as a power source but talking about its function in the water cycle.

In conception test, Deniz responded three questions related to the power sources. In the first question, she selected correct answer (please see ). In the next question, however, she failed to choose sun as a power source among the alternatives. Instead, she chose “atmosphere” with the confidence rating of “I am not sure”. Additionally, she selected that “Greenhouse gases warm the atmosphere and it affects as a power source in water cycle” In the last question, she failed to select “gravity” among the alternatives. She added an explanation to that question as “I think plants also affects water cycle. They produce water via transpiration, but unless streams flow, there would be no water cycle”. To sum up, she correctly responded one question out of three which may be an indicator that she had some difficulties to identify consistently the power sources of water cycle. Overall, her responses related to the power sources revealed that she had naïve understanding on the power sources of the water cycle, and she failed to name them.

#### **5.3.4.1.3 Components and Processes in Water System**

Within the context of the components of water system, she mentioned 22 of 31 components in the conception test, her drawings as well as during the interview. In the conception test, she identified ocean and groundwater as the biggest sources of water on Earth. In her drawing (Figure 5.32), she used the components such as plant, water, river, soil, clouds, rain, snow, water vapor, lake, and sea. On the other hand, she mentioned animals, human beings, fog, mountain, stream, creek, dew, glacier, sun, and ice during the interview in different occasions.

In terms of processes, she identified 10 processes of out 17. In her drawing (Figure 5.32), she indicated the processes of evaporation, condensation and precipitation. On the other hand, she mentioned melting, freezing, transpiration, capillarity, penetration, photosynthesis and respiration in different occasions during the interview.

During the data collection, Deniz reflected different components and processes. For example, she did not include all the processes and components that she identified in the conception test within her drawing. In her interview, she exemplified other components and processes. Overall, she exemplified 22 components of water system during the interview. Additionally, she named 10 processes of water system. In terms of procedural knowledge, she explained correctly some of the seven processes in the water system which will be given in the subsequent sections. While explaining the processes in evaporation and condensation, she revealed some misconceptions which were summarized in the previous section of “Properties of Water”.

#### **5.3.4.1.4 Interactions among the Earth Systems**

The analysis of Deniz’s responses emerged five different relationships among the Earth systems as (1) hydrosphere and atmosphere; (2) hydrosphere and biosphere; (3) hydrosphere and geosphere; (4) hydrosphere and anthroposphere; and (5) water cycle-oxygen cycle. Some of these relationships were mentioned by her through three or more different combinations. Each combination was given below.

The analysis of her drawing, interview, and responses of the conception test had some indicators about her understanding of the relationship between hydrosphere and atmosphere. For example, she explained her notion about the relationships between hydrosphere and atmosphere by indicating evaporation, cloud formation and precipitation in her drawing. While explaining the interaction between the two systems, I asked her to elaborate how clouds form in the interview. Her response was *“Frankly, I don’t know how clouds form. I have some knowledge about it, but they are not clear... I think they are composed of water vapor.”* She stated that she did not know how clouds form. However, when her responses related to clouds were examined, she stated that clouds are composed of water vapor which is partially correct. Hence, she had partial understanding on the mechanism of cloud formation such as evaporation, condensation and ingredients of the clouds. Unlike her vague explanations at the beginning of the interview, Deniz selected correct answers and

reasons for both questions (please see ). In short, she was able to reveal her declarative knowledge on how clouds by choosing the correct alternative in the test. Nonetheless, she had some difficulties to explain its processes which indicated that she had naïve understanding on how clouds form.

The relationships among hydrosphere, geosphere, and biosphere was detected in her drawing and the interview. When I asked, “*Is there any other system hidden in your drawing that might have an interaction with the water system?*” she emphasized the relationship among the hydrosphere, biosphere, and geosphere by giving two examples. First, she added a tree to her drawing and explained it as following:

Interviewer: How does water affects a tree?

Deniz: Okay... Water system affects, for example, two systems namely soil and tree. Precipitation does not have to be fall into water resources, it may also precipitate on the mountains or soil. Then, water penetrates the soil and absorbed by plants’ roots. Then it is used by trees, for example. Tree uses water in photosynthesis to produce food and other vital activities.

In addition to these, she also mentioned the interactions of hydrosphere – biosphere from another perspective as following:

There is also life cycle in aquatic life, and it interacts with the water in continental part. For instance, if the level of water in a sea or a lake decreases, aquatic life will be affected. Some marine species’ natural habitat would be deteriorated, and they would eventually die. Additionally, when the rate of evaporation increases, droughts may emerge.”

To sum up, she gave two examples for hydrosphere, geosphere, and biosphere relationships. She revealed both her declarative and procedural knowledge on this category.

Deniz reflected her notion related to the association between the anthroposphere and the hydrosphere in many instances. Instead of outlining all the instances, I only exemplified one of her excerpts below.

Interviewer: What are the components of your local water system?

Deniz: We are, for sure! We waste the water and we might influence other living organisms in our local water system because of this. We also affect the marine life in seas. If we throw our trashes to the sea, marine life will be affected badly. On the other hand, our water sources are depleting, droughts are emerging due to climate change. We do harm both living and nonliving things while we are using water recklessly...

In general, she exemplified the negative effects of people on the hydrosphere throughout the data collection. On the other hand, she explained partially how anthroposphere affects the hydrosphere negatively.

In addition to these, she also mentioned the oxygen cycle – water cycle interaction during the interview. She stated that “*We could plant trees to increase the amount of oxygen. Correspondingly, they would perform transpiration more.*” Deniz highlighted declaratively that tree is an agent to provide interaction between water cycle and oxygen cycle. In brief, when we examine [Figure 5.32](#) as well as her responses in different data collection instruments, we can summarize her functional systems literacy as following table. reviewed her knowledge not only in terms of level of correctness but also labeled that specific knowledge as declarative or procedural. Additionally, table also elaborated the incorrect responses as either it is a consistent and stable or it was produced *in-situ* which is inconsistent and unstable.

#### **5.3.4.1.5 Mapping the Interactions of the Categories in Functional Systems Literacy**

To explore the interactions among the categories in FSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. [Figure 5.33](#) revealed the map was given below. The details of the mapping were given under the methodology chapter. Based on the content analysis of this section, I can summarize Deniz’s functional systems literacy in water context as following:

- revealed that Deniz have mainly declarative knowledge on the basic mechanisms of the water system.

- In terms of procedural knowledge, she had naïve understandings on the working principles of the water system. At some points while examining the procedural knowledge, some misconceptions and incorrect in-situ answers were detected.
- [Figure 5.33](#) revealed that *Components of Water System* had most interactive categories among the others. In other words, while Deniz was talking about the basics of water system, she mostly used components of the water system.
- *Power Sources of the Water Cycle*, on the other hand, was the most limited category among the others. She integrated the power sources rarely into the other categories of FSL to explain the basics of the water system.



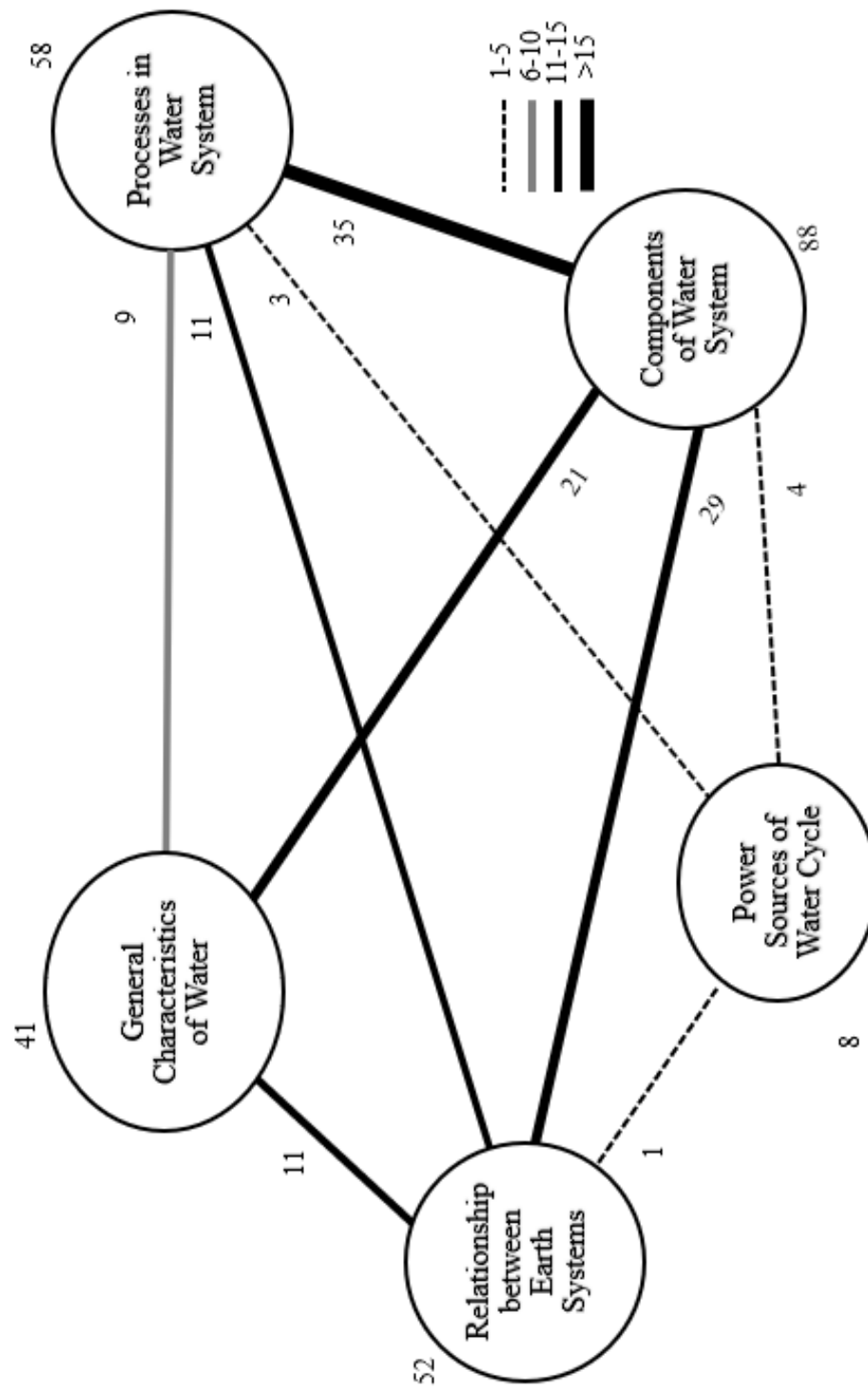
Table 5-17

## Summary of Deniz's Functional Systems Literacy in Water Context

| Categories / Codes*                                | Declarative /Procedural | Fully Correct Statement(s) | Partially Correct Statement(s) | Incorrect Statement(s) |               |
|----------------------------------------------------|-------------------------|----------------------------|--------------------------------|------------------------|---------------|
| Consistent                                         |                         |                            |                                |                        |               |
| Inconsistent                                       |                         |                            |                                |                        |               |
| General Characteristics of Water                   |                         |                            |                                |                        |               |
| Quantity of Water                                  |                         |                            |                                |                        |               |
| 1. Proportion of water resources                   | Declarative             |                            |                                |                        | ✓             |
| 2. Change in amount of water on Earth              | Procedural              |                            |                                | ✓                      |               |
| Cyclic nature**                                    | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            | ✓                              | ✓                      |               |
| Properties of Water                                | Procedural              |                            |                                |                        | ✓             |
|                                                    | Declarative             | ✓                          |                                |                        |               |
| Water in Living Organisms                          | Procedural              | ✓                          |                                |                        |               |
|                                                    | Declarative             | ✓                          |                                |                        |               |
| Power Sources of Water Cycle                       | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            | ✓                              |                        | ✓             |
| Components of the Water System (22 out of 31)      |                         |                            |                                |                        |               |
| Processes of the Water System (10 out of 17)       | Declarative             |                            | ✓                              |                        |               |
|                                                    | Declarative             |                            | ✓                              |                        |               |
|                                                    | Procedural              |                            | ✓                              | ✓                      |               |
| Relationship between the Earth System (5 out of 8) |                         |                            |                                |                        |               |
| Hydrosphere – Atmosphere                           | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            | ✓                              |                        |               |
| Hydrosphere – Geosphere                            | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            |                                |                        |               |
| Hydrosphere – Biosphere                            | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            |                                |                        |               |
| Hydrosphere – Anthroposphere                       | Declarative             | ✓                          |                                |                        |               |
|                                                    | Procedural              |                            | ✓                              |                        |               |
| Water cycle – Oxygen cycle                         | Declarative             | ✓                          |                                |                        |               |
| TOTAL (n)                                          |                         | 11<br>(8 D,3 P)            | 7<br>(2 D,5 P)                 | 4<br>(4 P)             | 2<br>(1D, 1P) |
| (D: Declarative, P: Procedural)                    |                         |                            |                                |                        |               |

**Figure 5.33**

*Mapping the Interactions among the Categories of Deniz's Functional Systems Literacy*





#### **5.3.4.2 Deniz's Cultural Systems Literacy**

Cultural systems literacy of Deniz traced through the second drawing task and phase 2 interview questions on CUSL. Her responses related to the basics of LWS was examined. [Table 5-18](#) indicated the categories and codes of Deniz's cultural systems literacy in water context.

##### **5.3.4.2.1 Components of Local Water System**

Components of LWS was examined through the second drawing task as well as phase 2 interview questions. Within the context of the second drawing task, the researcher expected Deniz to draw her local water system. However, her drawing was dominated by water supply network. Her notion related to the other components of water system, on the other hand, were traced during the interview. Her second drawing was given in [Figure 5.34](#).

In her drawing, precipitations such as rain, snow, and hail fill the dams and dams are used to provide water to her home. Water supply network (WSN) is a component of LWS which encompassed all icons within the drawing. There were also some icons related to sewerage system. The sub-categories of WSN and sewerage system will be variegated in the following sections.

During the interview, she also mentioned animals, plants, human beings, and some of the local water resources as components of LWS. Some of the components of LWS (LWR and WSN) were elaborated them in the following sections.

##### ***Local Water Resources***

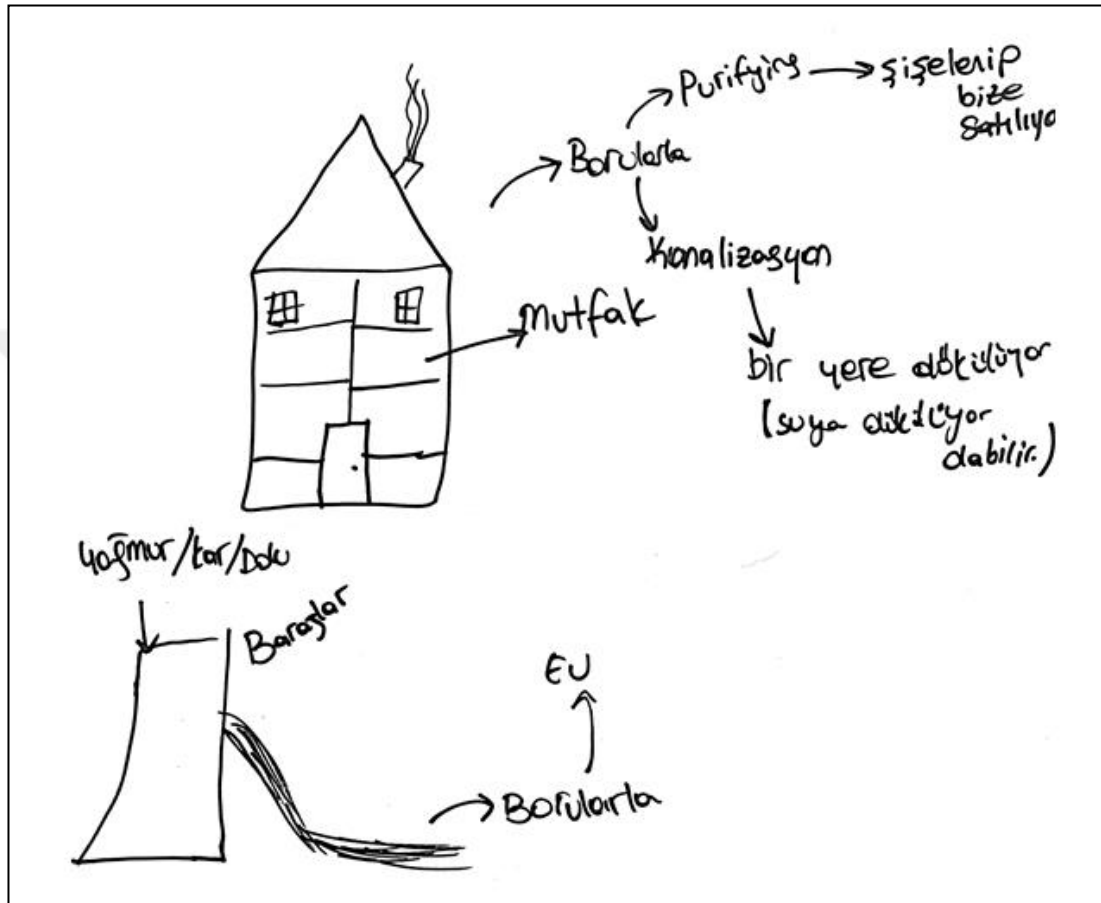
In terms of specific names and functions of LWR, Deniz identified that Lake Tuz and Lake Mogan are two of the local water resources in Ankara. Deniz stated during the interview that she does not know names of other local water resources such as rivers and dams.

**Table 5-18***Categories and Codes – Deniz’s Cultural Literacy*

| Theme: Basics of Local Water System (LWS)                               |                |                       |                          |                      |           |
|-------------------------------------------------------------------------|----------------|-----------------------|--------------------------|----------------------|-----------|
| Category 1: Components of LWS                                           |                |                       |                          |                      |           |
| Animal                                                                  | Human being    | Local Water Resources | Sewerage System          |                      |           |
| Plant                                                                   | Microorganisms | Water Supply Network  |                          |                      |           |
| Sub-Category 1.1: Local Water Resources                                 |                |                       |                          |                      |           |
| Sub-Category 1.1.1: Name of LWR                                         |                |                       |                          |                      |           |
| Lake Tuz                                                                | Lake Eymir     | Çubuk Dam             | River Kızılırmak         |                      |           |
| Lake Mogan                                                              | Kurtboğazı Dam | Aegean Sea            |                          |                      |           |
| Sub-Category 1.1.2: Functions of LWR                                    |                |                       |                          |                      |           |
| Survival                                                                | Recreational   | Energy source         | Industrial               |                      |           |
| Domestic                                                                | Economical     | Religious             | Agricultural             |                      |           |
| Sub-Category 1.2: Water Supply Network (WSN)                            |                |                       |                          |                      |           |
| Sub-Category 1.2.1: Components in WSN                                   |                |                       |                          |                      |           |
| River                                                                   | Hail           | Pipe                  | Drinking Plant           | Water                | Treatment |
| Cloud                                                                   | Water Puddle   | Engineers             | Water Storage Facilities |                      |           |
| Freshwater                                                              | Well           | Water ATM             | Fountain                 |                      |           |
| Rain                                                                    | Dam            | Home                  | Groundwater              |                      |           |
| Snow                                                                    | Lake           | People                | Sea                      |                      |           |
| Sub-Category 1.2.2: Processes in WSN                                    |                |                       |                          |                      |           |
| Precipitation                                                           |                | Water Distribution    |                          |                      |           |
| Water Accumulation                                                      |                | Water Treatment       |                          |                      |           |
| Sub-Category 1.3: Sewerage System                                       |                |                       |                          |                      |           |
| Sub-Category 1.3.1: Components in Sewerage System                       |                |                       |                          |                      |           |
| Pipe                                                                    |                | Receiving Environment |                          |                      |           |
| Wastewater Treatment Plant                                              |                |                       |                          |                      |           |
| Sub-Category 1.3.2: Processes in Sewerage System                        |                |                       |                          |                      |           |
| Wastewater Collection                                                   |                | Wastewater Treatment  |                          |                      |           |
| Category 2: National Water Resources (NWR)                              |                |                       |                          |                      |           |
| Sub-Category 2.1: Current State of NWR                                  |                |                       |                          |                      |           |
| Water Resources Potential                                               |                | Water Pollution       |                          |                      |           |
| Sub-Category 2.2: Name of NWR                                           |                |                       |                          |                      |           |
| Aegean Sea                                                              |                | Mediterranean Sea     | Lake Van                 | Uzungöl              |           |
| Black Sea                                                               |                | Marmara Sea           | Lake Dipsiz              |                      |           |
| Category 3: Relationship among Local, National, and Global (Sub)systems |                |                       |                          |                      |           |
| LWS- WSN                                                                |                | LWS -Biosphere        |                          | LWS -Atmosphere      |           |
| LWS -Hydrosphere                                                        |                | LWS -Geosphere        |                          | LWS - Anthroposphere |           |

**Figure 5.34**

*Deniz's Local Water System*



She explained, on the other hand, functions of LWR as following:

Interviewer: ...What are the names of water resources located in your hometown?

Deniz: There are lots of water resources, some of them dried, though. There are Lake Tuz, Lake Mogan...

Interviewer: So, who use these water resources in which purposes?

Deniz: In a simpler manner, there are living organisms in there, such as ducks (*she referred Lake Mogan*). They use water for surviving. On the other hand, there is no sea in Ankara. Hence, many people go around the lakes for recreational purposes by riding on a pedalo on the lake.

*(the conversation continues after the excerpt) ...*

Deniz: Unlike other living organisms, we use water for many other purposes. We are going around lakes for recreational purposes in Ankara because we do not have

seashore. But I don't think we drink lake water. It cannot be purified and used for drinking purposes, in my opinion.

In terms of local resources, she only named that she interacted with them for recreational purposes. Besides, she also stated the functions of the local lake in a way that living organisms in and around lake that depends on water. To sum up, Deniz only identified LWR that she visited in her hometown, but she failed to list further LWR. In terms of the functions of LWR, she explained they were used as survival and recreational purposes and they were not drinkable.

### ***Water Supply Network and Sewerage System***

During the second drawing task, Deniz explained where water coming from to her home as following:

Deniz: Water comes to my home from dams. But I don't know exactly how water in dams comes to my home... There are pipes, of course. But if there is another thing between them, I have no idea! We use bottled water that we buy from the market because we believe that we, the humanity, pollute the water resources. Thus, they are not drinkable anymore. We use the bottle water for drinking and cooking. The tap water, on the other hand, is used for other domestic purposes.

Interviewer: Okay then. So, where can be water coming from to dams? Could you please share your ideas if you have?

Deniz: *(thinks about a minute)* ... Water comes from the rain, snow, or hail.

The analysis of Deniz's responses indicated that she identified eight components and three processes in WSN in her hometown. On the other hand, Deniz explained her notion related to discharging of water as:

Deniz: After I use it, it goes to the sea via pipes. I saw it in a documentary, but I do not remember which one. In this video, wastewater accumulated in the sea... But it does not have to be discharged in every sea on the planet. For example, it could not be discharged into Mediterranean Sea that we swim... It will not be healthy for us. Wastewater, then, could be discharged to lakes or streams...

... *(the conversation continues after the excerpt)* ...

Interviewer: So, where does your home's wastewater be discharged?

Deniz: Maybe they are bottled and sold to us again like recycling as we did in plastics... But I have still doubt about it... It does not make any sense to me that the

water that we use our homes could be used again... this may not be the case... Maybe other dirty water except from our wastewater might be purified and sold us.

The analyses of her responses indicated two components and two processes in sewerage system in his hometown. Overall, Deniz has lack of knowledge on processes in dams, treatment systems at her hometown, and discharge process in Ankara. She stated that dams are filled by accumulated water via precipitation. Although she mentioned dams and pipes, she did not talk about treatment plants for both drinking water and wastewater located in her hometown. She guessed that the wastewater in Ankara discharged into a water resource without treatment which was not the case. The analysis of her responses on WSN and sewerage system revealed that her responses on this context was mainly *in-situ* answers which were inconsistent and unstable. The sources of information were based on her observations as well as secondary sources such as documentary.

#### **5.3.4.2.2 National Water Resources**

The responses related to national water resources (NWR) were classified into two categories as *Name of NWR* and *Current State of NWR*. She listed Mediterranean Sea, Marmara Sea, Lake Van, Lake Dipsiz, and Uzungöl as some of the national resources. She stated that she visited Marmara Sea and Uzungöl and shared her observations during her trip. On the other hand, she said that she saw Lake Dipsiz news on the media. In terms of current state of NWR, Deniz claimed that Turkey is not one of the water rich countries in the world. She explained it as even though we had so much water in our country, but exploiting it drifts us from being a water-rich country. She referenced her knowledge based on her experiences as well as news from the media. To sum up, even though she recognized several water resources in Turkey, she only identified NWR that she had trips around them, or media reported due to several reasons as in the Lake Dipsiz case. In terms of current state of NWR, she thought that Turkey is not one of the water-rich countries. In some instances, she talked about water pollution during the interview which will be given under the section of ‘Deniz’s critical

systems literacy'. She did not reveal her procedural knowledge on water pollution but addressed macro-pollutants such as trashes in freshwater.

#### **5.3.4.2.3 Relationship between Local and Global (Sub)systems**

The analysis of Deniz's responses emerged four different relationship among local and global (sub)systems as (1) LWS-Hydrosphere, (2) LWS-Atmosphere, (3) LWS-Anthroposphere; and (4) LWS- Biosphere perspectives. Some of these relationships were mentioned by her through triple combinations and more. Each combination was given in this section.

As I outlined in the WSN section, she thought that dams are filled by precipitation and she imagined that the wastewater that they discharge from their home might end up in a water resource which does not go back to her to be used again. She stated that it makes no sense to her to use the same water that they used before. Besides, she saw in a documentary that some wastewater discharges into the sea without treatment. All these indicators reflected her incomplete mental model on the relationship between her LWS in her hometown, atmosphere, and hydrosphere.

The second relationship that was the interactions between LWS and anthroposphere. She gave different instances from different places in her country as following:

Deniz: We are not one of those water rich countries... I have been seen its reasons on the news. They are reported that we use our water resources inefficiently. As an example, there was a news weeks ago about Lake Dipsiz. We tried to refill its water after we drained it for treasure hunt.

Interviewer: Hmm, I see... So, what about our national water potential?

Deniz: No... Even though our country is in the middle of three seas, we misuse them too. For instance, swimming in İstanbul (*referring Marmara Sea*) is impossible because sea trade leads to tremendous amount of water pollution in there...

*(the conversation continues after the excerpt) ...*

Another example is from the Black Sea Region. Uzungöl has a natural beauty. The shore is covered by the forest, but the tourists deteriorate the nature of the lake. They throw their trashes into the lake.

In these instances, given above, she was mainly talking about the negative effects of people on local water resources. She also mentioned Lake Dipsiz which was one of the popular news on the media. She complained about what happened to this lake. The way people use Uzungöl park was another example of her. She stated that Uzungöl and its surroundings is deteriorated by human being. Apart from these excerpts, she also addressed the effects of climate change and its interaction with the hydrosphere in different context during the interview. All these examples were the indicators for the relationship between LWS and Anthroposphere. The analysis revealed that even though she had declarative knowledge correctly on the interactions between LWS and Anthroposphere, her procedural knowledge was partially correct. She mentioned that seas and lakes were polluted by human beings due to different human activities, but she did not elaborate the mechanism of water pollution and its probable outcomes.

LWS, Biosphere and Anthroposphere relationships were also emerged from the analysis of Deniz's responses. While she was talking about functions of LWS, she stated that plants, living organisms that use water in the lakes, and people which can be considered as indicators for reflecting her declarative knowledge on the relationship between her LWS and biosphere. However, she revealed her procedural knowledge partially while she was mentioning the interactions between LWS and biosphere. She did not fully explain the processes within those interactions. For example, she did not explain how people waste the water and in what ways it influences the living organisms. In brief, when we examine [Table 5-18](#) as well as her responses in different data collection instruments (see [Figure 5.34](#)), we can summarize her cultural systems literacy in [Table 5-19](#).

#### **5.3.4.2.4 Mapping the Interactions of the Categories in Deniz's Cultural Systems Literacy**

[Figure 5.35](#) revealed the map. Cultural systems literacy of Deniz in terms of local water system can be summarized based on the content analysis of this section as following:

- [Table 5-19](#) revealed that Deniz have mainly declarative knowledge on the basic mechanisms of her local water system. In terms of procedural knowledge, she had naïve understandings on the processes in WSN. At some points while exploring her procedural knowledge on the basics of her LWS, some incorrect *in-situ* answers were detected.
- [Figure 5.35](#) revealed that *Relationship between Local and Global Systems* had most interactive categories among the others. In other words, while Deniz was talking about the basics of local water system, she mostly used this category to explain the basics of local water system. The remaining categories have nearly the same number of interactions. She integrated them into other categories.



**Table 5-19**

*Summary of Deniz's Cultural Systems Literacy in Water Context*

\* Not all

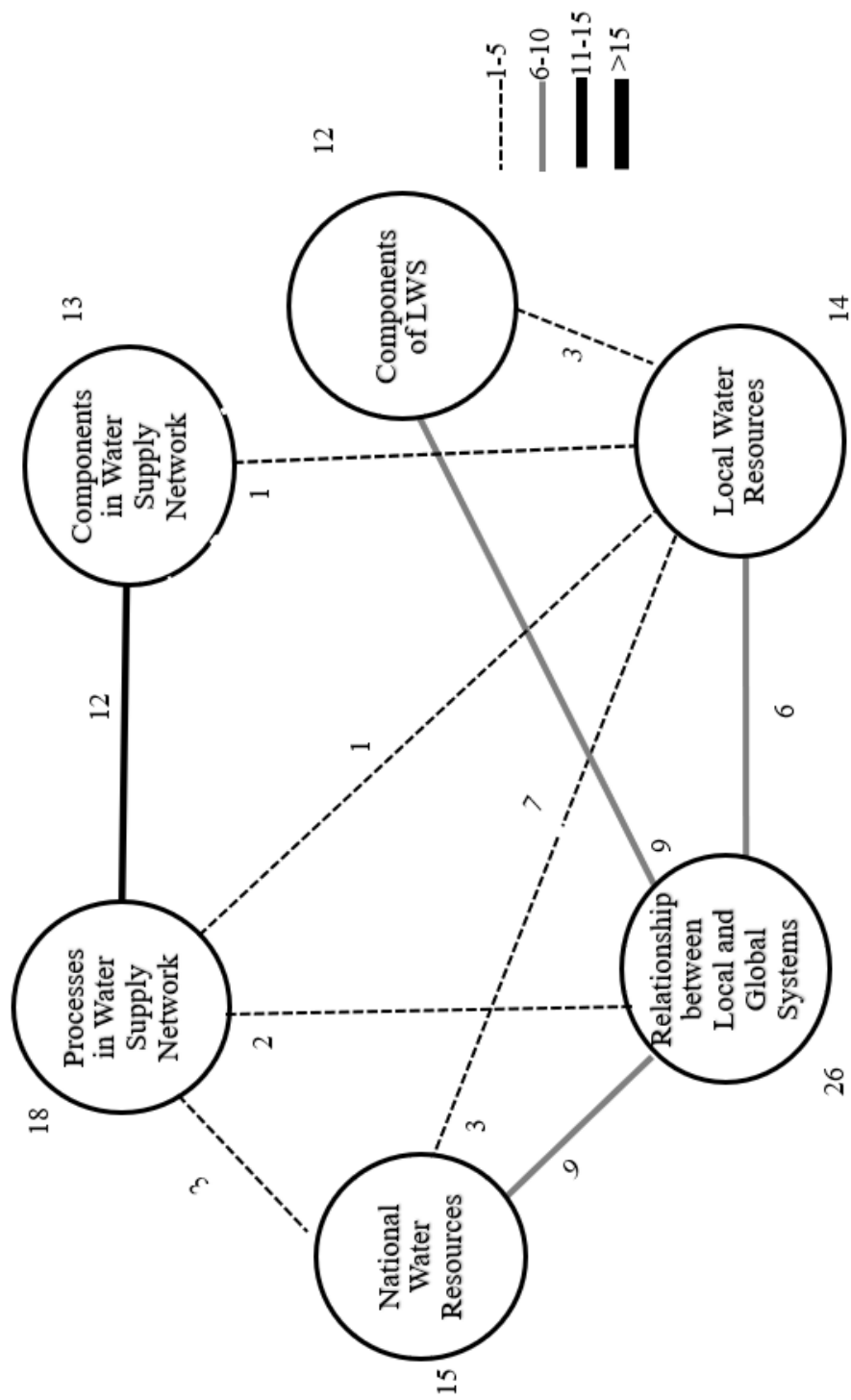
| Categories / Codes*                                  | Declarative<br>/<br>Procedural | Fully<br>Correct<br>Statements | Partially<br>Correct<br>Statements | Incorrect  |              | Don't<br>Know |
|------------------------------------------------------|--------------------------------|--------------------------------|------------------------------------|------------|--------------|---------------|
|                                                      |                                |                                |                                    | Consistent | Inconsistent |               |
| <b>Components of LWS</b>                             | Declarative                    | ✓                              |                                    |            |              |               |
| <b>Local Water Resources</b>                         |                                |                                |                                    |            |              |               |
| <b>Name of LWR</b>                                   | Declarative                    |                                | ✓                                  |            |              |               |
| <b>Functions of LWR</b>                              | Declarative                    |                                | ✓                                  |            |              |               |
| <b>Water Supply Network and Sewerage System</b>      |                                |                                |                                    |            |              |               |
| <b>Components</b>                                    | Declarative                    |                                | ✓                                  |            |              |               |
| <b>Processes</b>                                     |                                |                                |                                    |            |              |               |
| <b>Water Accumulation (Dams)</b>                     | Declarative                    | ✓                              |                                    |            |              |               |
|                                                      | Procedural                     |                                | ✓                                  |            | ✓            |               |
| <b>Water Distribution</b>                            | Declarative                    | ✓                              |                                    |            |              |               |
|                                                      | Procedural                     |                                | ✓                                  |            |              |               |
| <b>Drinking Water Treatment</b>                      | Declarative                    |                                |                                    |            |              | ✓             |
|                                                      | Procedural                     |                                |                                    |            |              | ✓             |
| <b>Wastewater Collection</b>                         | Declarative                    |                                |                                    |            | ✓            |               |
|                                                      | Procedural                     |                                |                                    |            |              | ✓             |
| <b>Wastewater Treatment**</b>                        | Declarative                    |                                | ✓                                  |            |              |               |
|                                                      | Procedural                     |                                |                                    |            | ✓            |               |
| <b>National Water Resources</b>                      |                                |                                |                                    |            |              |               |
| <b>Name of National Water Resources</b>              | Declarative                    | ✓                              |                                    |            |              |               |
| <b>Water Resources Potential</b>                     | Declarative                    | ✓                              |                                    |            |              |               |
|                                                      | Procedural                     |                                |                                    |            | ✓            |               |
| <b>Water Pollution</b>                               | Declarative                    | ✓                              |                                    |            | ✓            |               |
| <b>Relationship between Local and Global Systems</b> |                                |                                |                                    |            |              |               |
| <b>LWS- Atmosphere</b>                               | Declarative                    |                                | ✓                                  |            | ✓            |               |
|                                                      | Procedural                     |                                |                                    |            | ✓            |               |
| <b>LWS - Hydrosphere</b>                             | Declarative                    |                                | ✓                                  |            | ✓            |               |
|                                                      | Procedural                     |                                |                                    |            | ✓            |               |
| <b>LWS - Biosphere</b>                               | Declarative                    | ✓                              |                                    |            |              |               |
|                                                      | Procedural                     |                                | ✓                                  |            |              |               |
| <b>LWS - Anthroposphere</b>                          | Declarative                    | ✓                              |                                    |            |              |               |
|                                                      | Procedural                     |                                | ✓                                  |            |              |               |
| <b>TOTAL (n)</b>                                     |                                | 8                              | 10                                 | 0          | 9            | 3             |
| <b>Declarative (D)</b>                               |                                | (8D)                           | (6D, 4P)                           |            | (4D, 5P)     | (2D, 1P)      |
| <b>Procedural (P)</b>                                |                                |                                |                                    |            |              |               |

categories/codes were given in this table since some of them were not observed in all participants

\*\*\*Some categories/codes may have more than one answer since participants have both partially correct answer and accompanying misconception. OR they stated that they did not know the answer but tried to answer, though.

**Figure 5.35**

*Mapping the Interactions Among the Categories of Deniz's Cultural Systems Literacy*



### 5.3.4.3 Deniz's Critical Systems Literacy

The findings in this section will be given under these two themes as well as their categories. Themes and categories can be summarized as following in [Table 5-20](#).

#### 5.3.4.3.1 Advance Mechanisms of Water System

The theme of advance mechanisms of water system were given as following categories: dynamic nature of water system, causal dynamics and feedback loops, evolution of the system, and complexity of the water system.

##### 5.3.4.3.1.1 Dynamic Nature of Water System

As stated in the section of Quantity of Water, Deniz was not aware of that the total volume of the water is almost constant. This misconception was also emerged in this category. Her response on the dynamic effects of unconscious use of water was constructed based on her misconception were given below.

... Let's assume that the level of water in the dams decreased due to not having precipitation recently. If we used the water in dams recklessly, the level of water would decrease. On the other hand, the amount of evaporation from that dam is also decreasing. This would also lead to decrease the rate of precipitation. Since everything decreases, others are affected proportionally.

The analysis of her responses indicated that Deniz imagined that the water precipitates where it evaporates. She failed to consider precipitation and evaporation as dynamic concepts. However, in another context, she mentioned the effects of wind, while she was talking about redistribution patterns of the water as following:

... Let's talk about Antalya. Summers in Antalya is very hot. Last summer, however, it was raining when we went there. It is unexpected because the temperature is around 40°C in every July. Now, if there is a precipitation in Antalya in July, this could be attributed to the wind that pushes weather events. You know, when there are dark clouds on the horizon, it is a sign of a rain. First, I assume, the direction of wind is important. Let there be a heavy rain in İstanbul. Then, clouds are pushed by the wind and it may lead to another rain in Antalya. But, on the other hand, there would be more heavy clouds coming from the Black Sea Region due to its climate, geographical characteristics (*she referred having sea or lake*) and rate of evaporation... (*conversation continues*) ... Ankara doesn't have seashore so as Konya. But thanks to the winds, we have precipitations since it pushes the clouds. At once, we had heavy rain in Ankara and few days later, I saw on the news, there would be flood in İstanbul too.

**Table 5-20***Categories and Codes – Deniz's Critical Literacy*

| Theme 1: Advance Mechanisms in Water System                         |                                         |                 |
|---------------------------------------------------------------------|-----------------------------------------|-----------------|
| Category 1.1: Dynamic Nature of Water System                        |                                         |                 |
| CRDN111: Time Delay                                                 | CRDN112: Redistribution of Water        |                 |
| Category 1.2: Causal Dynamics and Feedback Loops                    |                                         |                 |
| CRFL121: Simple Open Loop                                           | CRFL123: Balancing Loop                 |                 |
| CRFL122: Reinforcing Loop                                           | CRFL124: Open Loop with multiple causes |                 |
| Category 1.3: Evolution of Water System                             |                                         |                 |
| CREV131: Decaying                                                   | CREV133: Toward higher organization     |                 |
| CREV132: Steady state                                               |                                         |                 |
| Category 1.4: Complexity of Water System                            |                                         |                 |
| Sub-Category 1.4.1: Interruptions in the Water System               |                                         |                 |
| CRCO1411: Climate Change                                            | CRCO1412: Hidden Use of Water           |                 |
| Sub-Category 1.4.2: Layers of Complexities                          |                                         |                 |
| CRCO1421: Environmental                                             | CRCO1424: Health                        |                 |
| CRCO1422: Economic                                                  | CRCO1425: Educational                   |                 |
| CRCO1423: Social                                                    | CRCO1426: Governmental                  |                 |
| Theme 2: Invisible Elements of Human System                         |                                         |                 |
| Category 2.1: Beliefs on Water Use                                  |                                         |                 |
| CRBL211: Self-use of water                                          | CRBL213: Sources of Beliefs             |                 |
| CRBL212: Collective use of water                                    |                                         |                 |
| Category 2.2: Self-efficacy towards Efficient Water Use             |                                         |                 |
| CRSE221: High                                                       | CRSE222: Low                            |                 |
| Category 2.3: Motive Concern                                        |                                         |                 |
| CRMC231: Social Altruistic                                          | CRMC233: Biospheric                     |                 |
| CRMC232: Egoistic                                                   |                                         |                 |
| Category 2.4: Action Strategies for Efficient Water Use             |                                         |                 |
| CRAC241: Persuasion                                                 | CRAC244: Reuse of water                 |                 |
| CRAC242: Water loss prevention                                      | CRAC245: Recycle of water               |                 |
| CRAC243: Reduce of water use                                        | CRAC246: No action                      |                 |
| Category 2.5: Emotional response                                    |                                         |                 |
| CREM251: Anger                                                      | CREM253: Happiness                      | CREM255: Apathy |
| CREM252: Sadness                                                    | CREM254: Proud                          |                 |
| Category 2.6: Motivational Orientation for Sustainable Use of Water |                                         |                 |
| CRMO261: Intrinsic motivation                                       | Amotivation                             |                 |
| CRMO262: Extrinsic motivation                                       |                                         |                 |

Unlike the former case, she included the effects of wind on the dynamic nature of water system. The analysis of her incoherent responses indicated that she produced *in situ* answers and was not be able to transfer her knowledge from one context to another. In another instance, she mentioned redistribution patterns of water as following:

To me, the total amount water on earth decreases and increases in time since the number of people is increasing. This increase leads to more water consumption.

..... (*the conversation continues after the excerpt*) ...

Different places on Earth experience different weather events. While some regions experience floods, some other regions experience droughts.

The analysis of this sample excerpt revealed that she attributed time delays to overpopulation and her misconception that “total amount of water decreases and increases in time on Earth”. Overall, the analysis of her response revealed that Deniz was aware of time delays and redistribution pattern of water in water system. However, her explanations about how these dynamical mismatches was based on her alternative conceptions.

#### **5.3.4.3.1.2 Causal Dynamics and Feedback Loops**

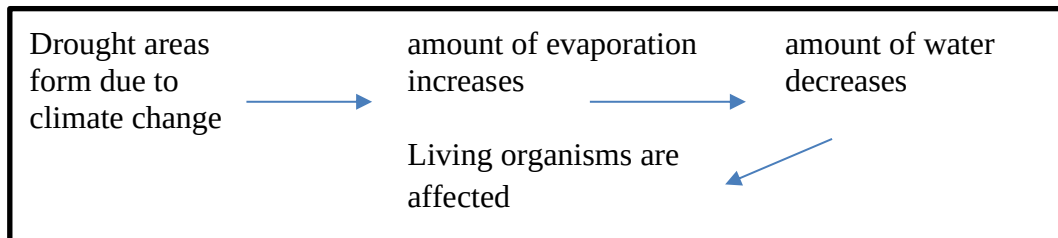
Causal dynamics were traced during the interview. During the interview, Deniz mentioned implicitly one simple open loop, one open loop with multiple causalities, and one simple reinforcing loop. Deniz reflected her notion of causality with an open loop while she was explaining the importance of living organisms. Her statement was following:

Actually, this water cycle... There is climate change though... droughts as an effect of climate change influences living organisms. So, are living organisms affecting the water cycle?... For example, if there is a severe drought, the amount of evaporation increases, and the level of water decreases too. Eventually, living organisms are affected...

Deniz’s statement can be classified as an open loop visualized as following:

**Figure 5.36**

*Deniz's Open Loop on Causalities in Water System*



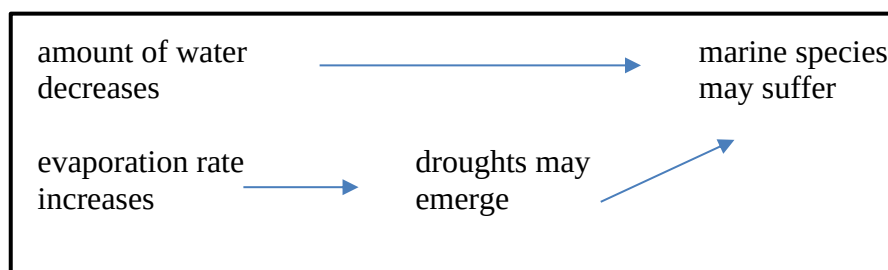
As given under the section of “*Relationship with Other System*” in FSL, Deniz mentioned some chain events about what would happen when there is more evaporation and decrease in amount of water.

There is also life cycle in aquatic life, and it interacts with the water in continental part. For instance, if the level of water in a sea or a lake decreases, aquatic life will be affected. Some marine species’ natural habitat would be deteriorated, and they would eventually die. Additionally, when the rate of evaporation increases, droughts may emerge.

Even though she did not explain these causalities in a feedback loop, she mentioned series of events when a disruption occurs and will eventually have negative effects on marine life. The visualization of these causal dynamics was given in Figure 5.37.

**Figure 5.37**

*Deniz's Open Loop with Multiple Causalities*



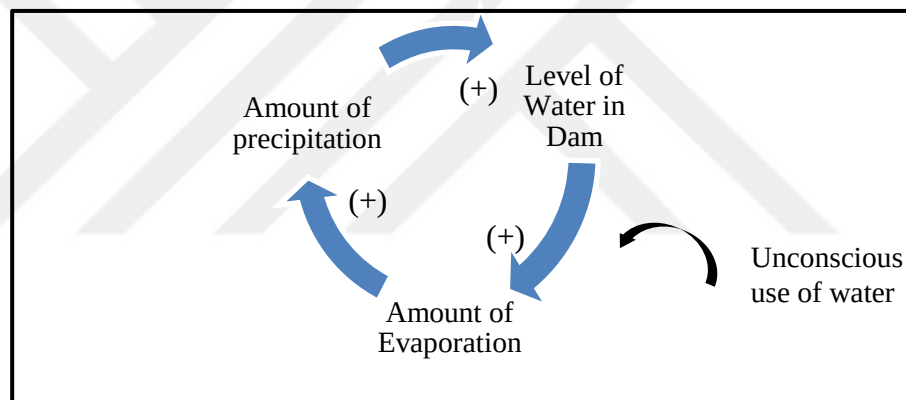
In terms of feedback loops, Deniz explained implicitly a simple reinforcing loop while she was talking about the effects of unconscious use of water. This answer was as one of the examples for reinforcing loops.

Let's assume that the level of water in the dams decreased due to not having precipitation recently. If we used the water in dams recklessly, the level of water would decrease. Consecutively, the amount of evaporation from that dam is also decreasing. Then, the rate of precipitation would also decrease again. Since everything decreases, others are affected proportionally.

The visualization was given in the [Figure 5.38](#).

**Figure 5.38**

*Deniz's Reinforcing Loop*



In the figure, Deniz's notion was summarized as when the amount of precipitation decreases, then the level of water in a dam would also decrease. Unconscious use of water of people would contribute to the decrease in the level of water in the same dam. So, amount of evaporation in that dam decreases too as a result of decrease in the level of water. These chain events, eventually, would also decrease the amount of the precipitation itself and this creates a loop.

Overall, Deniz revealed her notion of causality in a system by explaining chain events in open loops with multiple causalities, reinforcing loop, and simple open loop. While

she was explaining her notion on the causalities, she mainly attributed to the effects on living organisms.

#### 5.3.4.3.1.3 Evolutionary Processes in Water System

Deniz addressed possible evolutionary scenarios for her national water system and the global water system. The sample excerpt for her national water system context was following:

I live in Turkey. I don't want to be certain, but I think we suffer from water scarcity substantially in the future... But it is going worse, I mean... What would be in the future? Of course, the water cycles but with less precipitation or quite the opposite, more precipitation and no drought. I think there is a bad future in front of us because we consume water recklessly. We don't think about what will happen in the future. We only think about ourselves... Eventually, we are the ones who couldn't live in this way. We are the ones who kill ourselves.

Besides, while she was also talking about Turkey's water potential in the former sections, she exemplified from the mass media (Lake Dipsiz in [page 290](#)) which can be another indicator for her notion of the evolution. Overall, her statements reveal that she interpreted the evolution of her local water system as decaying. In terms of global aspects, she remained undecided:

I think we are unconscious (*referring people in Turkey*) but I reckon that there are conscious countries too in terms of water use... (*the conversation continues*) ... I think the amount of water would decrease on Earth since it is an open system... (*the conversation continues*) ... I don't have any idea if sea level decreases or not, but I think that we approach to be water poor in worldwide... the amount of water would decrease, in my opinion. Yet, it needs to be explored whether it decreases or not.

She seemed that she was undecided about the future of the global water system. Even though she was prone to decide decaying due to human use of water, she also assumed that there are countries that are conscious in water use. Still, she suggested that this could be explored if this is the case or not. To sum up, she predicted that her local water system is decaying due to unconscious use of water, but she was neutral about the future of the global system due to having conscious countries in terms of water use.



#### 5.3.4.3.1.4 Complexity of the Water System

##### *Climate Change and the Water System*

Content analysis of her responses related to the complexities of the water system revealed that Deniz could be able to detect interruptions in the water system and layers of its complexity. I asked to her “*What happened to the water system in this story?*” Her rationale was following:

Deniz: The water system in there... I think it was disrupted because... Wait a minute... Huh... It was disrupted because rain started suddenly, and it damaged the flowers of the fruits. Actually, the rain should be slow in springs to let flowers bloom and turn into fruits. But in this story, downpour was occurred, and it was not expected. This unforeseen rain didn't let ripen to fruits.

Interviewer: Okay, thank you. So, it was written that the seasons began earlier than expected. What could be the reason for it?

Deniz: I could say climate change, global warming. Actually, we are also experiencing the effects of them because we are in November and the weather is hotter than before. The New Year's Day is not snowy anymore in Ankara... (*the conversation continues*) ... the snow can be observed in February and March which were not the case before. The seasons were shifted. They change.

Deniz detected the failure of the water system within the case as climate change but not give the detail on the reasons or mechanisms of the climate change. In terms of layers of complexities, she mentioned the effects of climate change on the economic, social, environmental, and health perspectives. Sample excerpts were given below.

Plants and people are being affected by the seasonal anomalies because the number of illnesses is increasing in the mid-season. During the ripening period, the weather becomes suddenly cold and fruits are wasted. Then, to overcome the loss of fruits and increase efficiency, we produce GMOs (*this was not in the story*) which, in turn, affects our health because we eat them. Hence climate change has effects on us, and the plants.

... (*the conversation continues after the excerpt*) ...

I think we are the reason for it (*referring climate change*) and we are the ones who are, in turn, suffered from it. Similarly, plants, animals, and insects are also suffered... No, I don't want to include insects (*she laughed*)

... (*the conversation continues after the excerpt*) ...

If I were a farmer in that village, I would be disappointed over losing my crops. My crops would be grown only in that season. I would have to harvest my fruits on time so that I would sell them. I would need to live on and meet my needs. Farming would be my economic source that I solely depend on.

In short, Deniz was able to identify the failure of the water system as climate change. Moreover, she identified four different layers of complexity as economic, social, environmental, and health perspectives.

### *Hidden Use of Water and The Water System*

When I asked Deniz about the term “hidden use of water” during the interview, she said she has never heard this term before. As she did not know the meaning, I asked her to think about whether there would be water consumption in foods that we eat or the clothes that we wear. Her inference process was given below.

*... (the conversation continues before the excerpt) ...*

Deniz: Yes, of course. For instance, while manufacturing the denim jeans, there are lots of water consumed. I watched it in a video. They washed the jeans couple of times. Then, denim grinding machine was also another source of water consumption during the grinding process. Our water decreases due to clothing industry. I watched only this video, but I think there would be also water consumption in other clothing processes.

*... (the conversation continues after the excerpt) ...*

I asked Deniz to think about possible water consumption in a hamburger. The inference process of Deniz were given as following:

Interviewer: What about, for instance, a hamburger? Do we spend water for it?

Deniz: There is lettuce in hamburger. people consume water while they wash them. It's same for tomato. You should wash with plenty of water. Additionally, you should also add some vinegar in the water to disinfect the vegetables. On the other hand, I don't think we spend water while producing the meat. However, we spend also water while leavening the bread. In drinks, of course, there is water consumption.

*... (the conversation continues after the excerpt) ...*

Vegetables are grown by the farmers or in the soil and they are irrigated by them. On the other hand, meat comes from animals and animals drink water for surviving. Animals' food like forage also needs water to be grown.

Interviewer: OK, when you think about the process of hamburger production, who are responsible for the consumption of water?

Deniz: We, the people. Farmers and choppers. They can be either good or bad people according to their water consumption during irrigation or preparation.

The analysis of the conversation revealed that Deniz had no declarative knowledge about the term “hidden use of water”. However, when more elaborative questions were asked about water consumption in a product, for example, she had the ability to infer consumption of water at some level, but she neglected the water for hamburger’s packaging process as well as wastewaters spent for the production. This indicated that she had procedural knowledge partially about the processes during the production. Despite these inferences, she still believed that she is not responsible for the water consumption in agricultural and industrial farming. She thought that the other people were responsible for water consumption.

#### **5.3.4.3.2 Invisible Elements of Human System**

In this section, the findings were given within the categories of beliefs about water consumption behavior, emotional responses, motive concerns, action strategies for efficient water use, self-efficacy beliefs towards efficient water use, and motivational orientation for sustainable water use.

##### **5.3.4.3.2.1 Beliefs on Water Use**

###### *Beliefs about Self-use of Water*

Self-use of water was traced in the interview part. The analysis of Deniz’s responses indicated that she had inferential beliefs. These beliefs were summarized one by one with their sources of the beliefs.

Deniz had inferential beliefs as (1) I am a conscious consumer of water; (2) I am more conscious than other people in terms of efficient water use; and (3) I am not responsible for the water consumption in agricultural and industrial farming. To explore the nature of her water consumption behavior, I asked to her in which activities does she consume water in a day. She stated that she uses water daily in bathroom, restroom and the kitchen. Besides, she added that she turns off the tap while she was brushing her teeth

and do not flush the toilet more than once. On the other hand, since she is a volleyball player, she mentioned that she takes a bath almost every day. To decrease her water consumption, however, she said she tries to take quick showers. She finished her explanation as *“I use water if and only if I need it.”*

She shared another inferential belief as *“Sometimes, I realize that the taps are remained open in the school restroom. People may either forget to turn off or don’t care about it. I think I am more conscious about it.”* She believed that she is more conscious than other people based on her beliefs that *“I am a conscious consumer of water.* She made comparison and inferred that she was more conscious than other people.

In terms of hidden use of water aspect, she mentioned before that she did not know the meaning. However, she inferred some of the water consumption processes during agricultural and industrial farming. Despite these inferences, she believed that people working in these processes (i.e., farmers) were responsible for the water consumption. This belief was classified as inferential belief since she attributed water consumption based on the direct use of water. According to her, since she was not spending water for the tomato in her hamburger since she was not there to irrigate it in the fields. This rationale was based on the attribution to the direct use of water.

Analysis of her responses revealed that she had inferential beliefs inferred from her daily experiences related to direct use of water. Since she did not know the concept of hidden use of water, which was given in the previous section, she failed to consider her hidden use of water.

#### *Beliefs on Collective Use of Water*

In this part, the role of people in water system was asked to trace Deniz’s beliefs on collective use of water. She had inferential and informational beliefs related to the collective use of water. Each of them was given below.

She had two beliefs that (1) People are one of the factors affecting the water system and (2) People have negative effect for this system. The sources of her beliefs were based on not only her direct experiences but also some outside sources. Thus, these beliefs were classified as both descriptive and informational belief. She also had an inferential belief that “*We are in the middle of the water system*”. Each of them was given in detail.

Deniz shared her beliefs on the collective use of water multiple times during her interview. Some of the excerpts were given below.

... (*the conversation continues before the excerpt*) ...

Deniz: There is a balance on Earth, and we disturb this natural balance. Let me give an example from today. There is a heavy fog in these days, and this is because of us. We see extreme weather events in worldwide. For instance, the last summer was too hot. This hotness led to an increase in the rate of evaporation... (*the conversation continues*) ... This is because we disturbed the balance.

... (*the conversation continues after the excerpt*) ...

Every move we make change the nature. Different patterns can be form or things may increase or decrease because of us. I believe nature get back its old days if human being becomes extinct. I couldn't imagine a living organism that its effect is worse than ours. Yet, we seldom have positive effects such as planting trees to get increase the oxygen level. But most of the time, we have negative effects. We don't think about nature since we use it for our self-interest.

In addition to these sample excerpts, she stated that people have negative effects of the water system by sharing her direct experiences during her trips (i.e., the Marmara Sea, Uzungöl). Moreover, she also mentioned that she saw Lake Dipsiz case on the TV. The analysis of her experiences summarized before and these sample excerpt revealed that she formed her inferential beliefs based on these experiences.

In terms of the inferential belief that “*We are in the middle of the water system*”, she explained sources of beliefs as following:

We are not the head of the system; we are in the middle of it. We influence its evaporation rate. Water could evaporate itself without our help, but we exacerbate the climate and the environmental condition. This affects the rate of evaporation directly or inversely... (*conversation continues*) ... we have negative effects on the water system. I do not think that we have positive effects on it.

The analysis of her sample excerpts as well as her other responses during the interview revealed that she formed inferential belief, and informational beliefs for the collective use of water. Her sources for these beliefs were reported in different instances on the interview such as direct experiences, school, and media.

#### **5.3.4.3.2.2 Action Strategies for Efficient Water Use**

In this section, participants' explicit statements about their action strategies for efficient or sustainable water use was given. As Deniz reported that she did not remember the context of sustainability, the interview was built based on her action strategies for efficient water use. Correspondingly, I asked her to explain whether she set a goal related to efficient water use in her daily life. Her response was following:

Deniz: For example, I know it's a cliché, I turn of the tap while I am brushing my test. I avoid flushing the toilet many times. I drink only the amount of water that I need. In general, I don't use water more than I need.

The sample excerpt revealed that her action strategies were related to her direct use of water. She did not share any action strategies related to her hidden use of water because she already reported that she did not know the meaning of the term. Her action strategy was classified as reduce of water use.

#### **5.3.4.3.2.3 Self-Efficacy Beliefs towards Efficient Water Use**

While she was talking about her action strategies given above, she believed that she used water only when she needs it. She shared her strategies on how to use water efficiently in terms of direct use of water. This was an indicator that she had relatively high self-efficacy towards being efficient user of water. She did not give detailed information about how she uses water efficiently in terms of hidden use of water. Thus, it indicated that her self-efficacy belief toward efficient water use was not based on her actual behavior.

#### **5.3.4.3.2.4 Emotional Response**

Her emotions related to effects of people on the water system were asked. She said she was sad for the nature since she read on the news that we should look for another planet to live by 2023. She stated that we pollute the water resources and we don't consider the rate of degradation of the pollutants in the nature. The analysis of her responses indicated that sadness was her emotional responses that she had related to the water system.

#### **5.3.4.3.2.5 Motive Concern**

To reveal the motive concerns of Deniz on the importance of water system, several questions were asked during her interview. First, the importance of water system was asked. She explained her view as following:

Let's assume that there is no precipitation at all. Then, what about the nature and natural resources? How our dams will be filled, how plants will perform photosynthesis? Plants are very important because they produce oxygen. Water is also important for them since plants do many things for the sake of humanity.

While Deniz shared her ideas about maintenance of water system, she emphasized nature, plants, and human beings who are possibly be affected from disrupted water cycle. This response was an indicator of his biospheric and social altruistic motive concern. However, she emphasized that she considered plants significant due to their importance for people' life. Therefore, this was an indicator of her dominant motive concern as social altruistic for this question. Nevertheless, she reflected her biospheric motive concern in many instances during her interview. In short, Deniz hold different motive concerns about the present state of water system, but no dominant motive concern was detected in her responses.

#### **5.3.4.3.2.6 Motivational Orientation**

As presented in the previous sections, Deniz used water efficiently and shared her strategies in terms of her direct use of water. In terms of motivational aspect, it was

asked to Deniz that the sources of her motivation if any to use water efficiently. Her specific answer related to that question was following:

If I didn't use it efficiently, we would be affected badly. We need water as much as the animals need. If we didn't use it wisely, there would be no water in the future for us. Plants and animals may survive since they use it only for survival needs. For example, an animal can eat its food without cleaning it with water. But this is not the case for us. I make provision against water scarcity because it's my future. I motivate myself that way. Nobody gets hurt due to my actions, not only me but also all the others (*she referred all the living organisms*).

The analysis of her responses indicated that she had *external motivation*. In her case, Deniz used water efficiently since water is important for all life on Earth. The importance of performing behavior provided a basis for her actions.

#### **5.3.4.3.3 Summary of Deniz's Critical Systems Literacy in Water Context**

The analysis of Deniz's critical systems literacy in water context were given in two themes. In terms of *advance mechanisms of water system*, Deniz's explanations were categorized in four categories. In term of dynamic nature of water system, she referred dynamical mismatches through exemplifying time delays and redistribution of water. Her procedural knowledge about how these dynamical mismatches occur based on her alternative conceptions.

On the other hand, she exemplified causal dynamics by explaining them as one simple open loop, one open loop with multiple causalities, and one simple reinforcing loop. In terms of evolutionary processes in the system, she predicted that her local water system is decaying due to unconscious use of water, but she was neutral about the future of the global system. Last, Deniz's reflections related to the real story can be an indicator of her notion on the complexity of the water system. She detected climate change as a disruption in the water system and she mentioned the layers of complexities as economic, social, environmental, and health dimensions. In terms of hidden use of water, however, she had no declarative knowledge, but was able to infer some of the processes during the manufacturing of the products. Besides, she claimed that she was not responsible for the water consumption in the products that she bought.



Under the theme of *invisible elements of human system*, Deniz's responses were examined by means of six categories. In terms of beliefs on water consumption behavior, she reflected her beliefs on self-use and collective use of water. She gave detailed information about the sources of her beliefs. She had descriptive and inferential beliefs related to self-use of water. Descriptive beliefs were based on her daily life experiences. She attributed her inferential belief to her descriptive beliefs. On the other hand, she had descriptive, inferential, and informational beliefs on the collective use of water. Her sources for these beliefs were reported in different instances on the interview such as direct experiences, school, and media.

Deniz's action strategies were related to her direct use of water. She did not share any action strategies related to her hidden use of water because she did not know the term. Her action strategy was classified as reduce of water use. Her statements also revealed that she had high self-efficacy while she mentioned her direct use of water. Sadness and happiness were the two emotional responses that she had related to the water system. While she was talking about the importance of water and water system, biospheric and social altruistic value orientations were observed as motive concerns. Deniz hold these different motive concerns about the present state of water system, but no dominant value orientation was detected in her responses. Last, she attributed her motivation about efficient use of water to consider the importance of water for living organisms as well as humanity. Thus, she had extrinsic motivation since she exhibited this behavior because of its perceived usefulness and importance.

#### **5.3.4.4 Mapping the Interactions of the Categories in Systems Literacy**

To explore the interactions among the FSL, CUSL, and CRSL, in-depth analysis of the written transcription was conducted. Based on the content analysis, an interaction map was produced. Figure 4.43 revealed the map. The order of the interactions from highest to the lowest among the elements of systems literacy was FSL-CRSL, FSL-CUSL, and CUSL-CRSL.

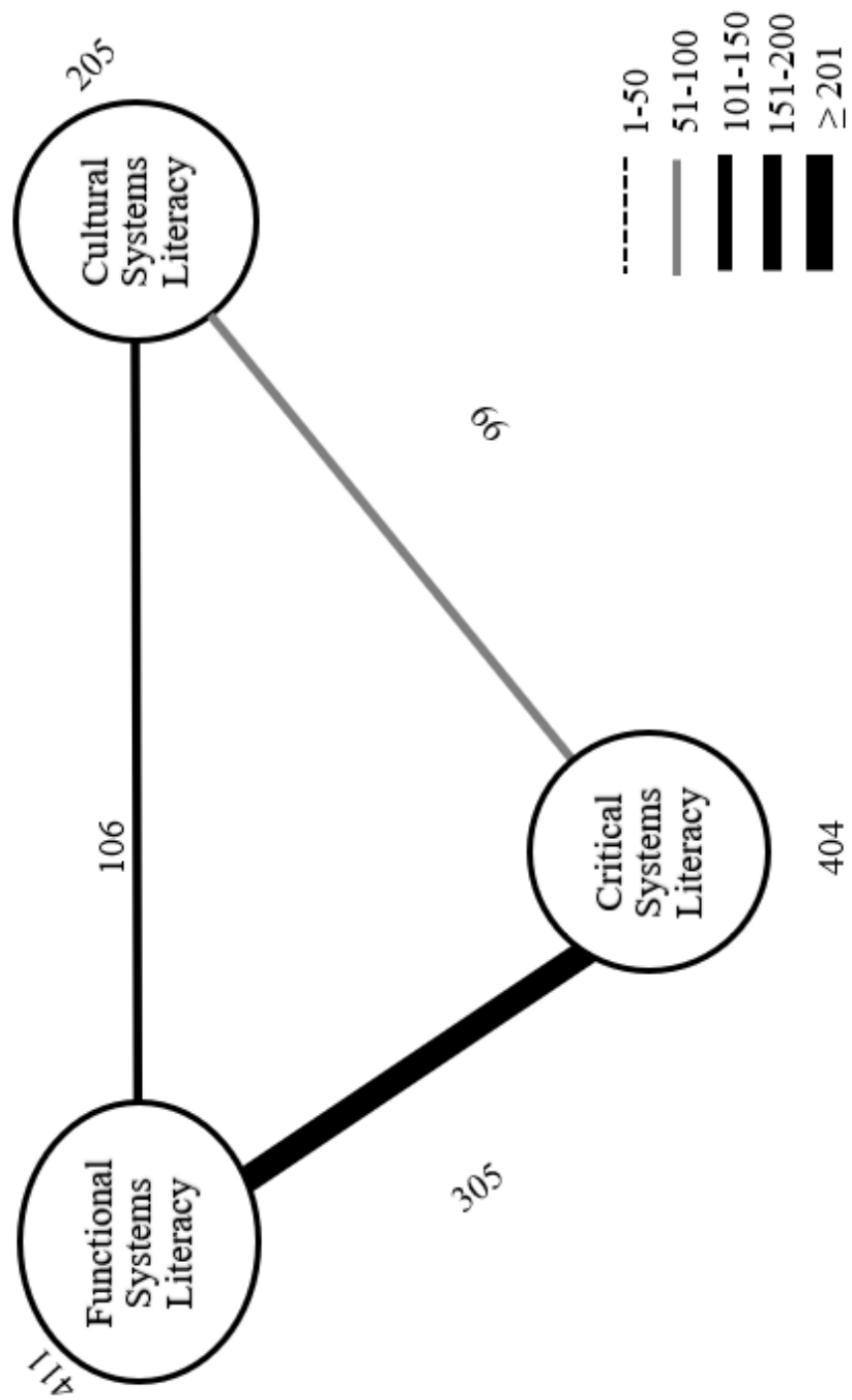
The interactions among the elements of systems literacy of Deniz in terms of water system can be summarized based on the content analysis of this section as following:

- Figure 5.39 revealed that *Functional Systems Literacy* and *Critical Systems Literacy* had similar number of interactions, whereas *Cultural Systems Literacy* was least interactive.
- The number of interactions between *Functional Systems Literacy* and *Critical Systems Literacy* were higher than the other combinations of interactions (FSL – CUSL; CUSL-CRSL).



**Figure 5.39**

*Mapping the interactions among Deniz's systems literacy elements in water context*



### **5.3.5 Comparative Analysis of Four Cases: The Findings of Cross-Case Analysis**

This section summarized the comparison of the findings across cases. In the first part, the patterns of functional systems literacy across the cases were presented. Moreover, alternative conceptions of cases were listed. Consecutively, the comparisons of cultural systems literacy and critical systems literacy were given.

#### **5.3.5.1 Comparison of Functional Systems Literacy across Cases**

As stated in the previous section, the patterns of FSL were traced through the conception test, first drawing task and interview questions of phase 1. In this part, comparison of each category and interaction maps were summarized. While examining the content of each category, the frequency of responses for each category was also calculated (please see [Table 5-22](#)). To have a closer look, both declarative and procedural knowledge were traced in case's responses summarized in [Table 5-21](#). In terms of general characteristics of water, the frequency of statements that included procedural knowledge were lower than declarative knowledge in all four cases. Specifically, Eren and Ahmet had more fully correct statements in both declarative and procedural knowledge than Deniz and Cansu. In terms of quantity of water, Eren and Ahmet were aware of that the amount of water on Earth is almost constant, whereas Cansu and Deniz had alternative conceptions (see [Table 5-23](#)). Cyclic nature was mentioned by all cases except Deniz. Three cases stated that water cycles in nature, but they failed to explain the entire process which was an indicator of lack of procedural knowledge. The category of 'properties of water' was emerged in the analysis of Ahmet and Deniz's responses. They mentioned the mechanism of evaporation as one of the physical properties of water. Whereas Ahmet had fully correct statements about evaporation, Deniz had some alternative conceptions that interfere with her notion of evaporation (see [Table 5-23](#)).

**Table 5-21***Frequency Table of Categories in FSL*

| Categories of FSL                               | Case  | Frequency<br>(n) | Percentage<br>( $p = n/N \times 100$ ) |
|-------------------------------------------------|-------|------------------|----------------------------------------|
| Power Sources of Water Cycle<br>(N = 3)         | Eren  | 2                | 66.67%                                 |
|                                                 | Cansu | 3                | 100.00%                                |
|                                                 | Ahmet | 2                | 66.67%                                 |
|                                                 | Deniz | 3                | 100.00%                                |
| Components of Water Cycle<br>(N = 31)           | Eren  | 18               | 58.10%                                 |
|                                                 | Cansu | 18               | 58.10%                                 |
|                                                 | Ahmet | 20               | 64.52%                                 |
|                                                 | Deniz | 22               | 70.97%                                 |
| Processes of Water Cycle<br>(N = 17)            | Eren  | 7                | 41.12%                                 |
|                                                 | Cansu | 4                | 23.53%                                 |
|                                                 | Ahmet | 6                | 35.29%                                 |
|                                                 | Deniz | 10               | 58.82%                                 |
| Relationship among the Earth Systems<br>(N = 8) | Eren  | 5                | 62.50%                                 |
|                                                 | Cansu | 4                | 50.00%                                 |
|                                                 | Ahmet | 7                | 87.5%                                  |
|                                                 | Deniz | 5                | 62.5%                                  |

Water and living organisms were mentioned by all cases. Whereas all cases had fully correct declarative knowledge statements, only Eren and Deniz had fully correct procedural knowledge statement. Last, relational responsiveness was emerged in all cases' responses except Deniz. Ahmet explained both living and non-living subsystems' reactions. Eren mentioned solely non-living reaction, whereas Cansu explained the living subsystem's reaction when a change occurs in the water system. [Table 5-21](#) and [Table 5-22](#) revealed that Cansu and Deniz listed all three power sources declaratively but Ahmet and Eren failed to state wind as a power source. The number of components in water system were mostly higher in responses of Ahmet (64.52%) and Deniz (58.82%). Among these 31 components, none of the cases mentioned rock, aquifer, hail, and freshwater. The number of processes in water system was the highest in Deniz' responses. Deniz mentioned 10 processes out of 17 (58.82%). In terms of procedural knowledge, only Eren had fully correct statements in this category, whereas Cansu and Deniz had some alternative conceptions and *in-situ* answers.

Table 5-22

Frequency Table of Comparative Analysis of FSL

| Category of FSL                            | Case  | Fully Correct Statement(s) |                         |                        | Partially Correct Statement(s) |                         |                        | Incorrect Statement(s)   |                         |                        |
|--------------------------------------------|-------|----------------------------|-------------------------|------------------------|--------------------------------|-------------------------|------------------------|--------------------------|-------------------------|------------------------|
|                                            |       | Declarative<br>( $n_1$ )   | Procedural<br>( $n_2$ ) | Total<br>( $n_1+n_2$ ) | Declarative<br>( $n_3$ )       | Procedural<br>( $n_4$ ) | Total<br>( $n_3+n_4$ ) | Declarative<br>( $n_5$ ) | Procedural<br>( $n_6$ ) | Total<br>( $n_5+n_6$ ) |
| General Characteristics of Water           | Eren  | 4                          | 3                       | 7                      | -                              | 1                       | 1                      | -                        | 1                       | 1                      |
|                                            | Cansu | 3                          | -                       | 3                      | -                              | 3                       | 3                      | -                        | 2                       | 2                      |
|                                            | Ahmet | 5                          | 3                       | 8                      | -                              | 2                       | 2                      | -                        | -                       | 0                      |
|                                            | Deniz | 2                          | 1                       | 3                      | -                              | 1                       | 1                      | 1                        | 3                       | 4                      |
| Power Sources of Water Cycle (x/3)         | Eren  | -                          | 1                       | 1                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
|                                            | Cansu | 1                          | -                       | 1                      | -                              | 1                       | 1                      | -                        | -                       | 0                      |
|                                            | Ahmet | -                          | -                       | 0                      | 1                              | 1                       | 2                      | -                        | -                       | 0                      |
|                                            | Deniz | 1                          | -                       | 1                      | -                              | 1                       | 1                      | -                        | 1                       | 1                      |
| Components of Water Cycle (x/31)           | Eren  | -                          | -                       | 0                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
|                                            | Cansu | -                          | -                       | 0                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
|                                            | Ahmet | -                          | -                       | 0                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
|                                            | Deniz | -                          | -                       | 0                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
| Processes of Water Cycle (x/17)            | Eren  | -                          | 1                       | 1                      | 1                              | -                       | 1                      | -                        | -                       | 0                      |
|                                            | Cansu | -                          | -                       | 0                      | 1                              | 1                       | 2                      | -                        | 1                       | 1                      |
|                                            | Ahmet | -                          | -                       | 0                      | 1                              | 1                       | 2                      | -                        | -                       | 0                      |
|                                            | Deniz | -                          | -                       | 0                      | 1                              | 1                       | 2                      | -                        | 1                       | 1                      |
| Relationship among the Earth Systems (x/8) | Eren  | 4                          | -                       | 4                      | 1                              | 4                       | 5                      | -                        | 1                       | 1                      |
|                                            | Cansu | 2                          | -                       | 2                      | 2                              | 3                       | 5                      | -                        | 1                       | 1                      |
|                                            | Ahmet | 7                          | -                       | 7                      | 1                              | 4                       | 5                      | -                        | 1                       | 1                      |
|                                            | Deniz | 5                          | 2                       | 7                      | -                              | 2                       | 2                      | -                        | -                       | 0                      |

The last category was related to the relationships among the Earth (sub)systems. The frequency of statements that included procedural knowledge were lower than declarative knowledge in all four cases. Among the cases, Ahmet mentioned almost all relationship between the systems available in the codebook except for water cycle-oxygen cycle. Nevertheless, almost all of his statements were related to his declarative knowledge. He failed to indicate his procedural knowledge on this category. Deniz had fully correct statements in terms of both declarative and procedural knowledge. The other two participants had partially correct statements in terms of procedural knowledge. Lastly, all four cases revealed some alternative conceptions and in-situ answers while they were talking about the relationships between the Earth systems.

Enumerative approach enabled to see the map of interactions among the categories of FSL of a case. [Figure 5.40](#) summarized the comparison of FSL interaction maps of cases. The findings can be summarized as following:

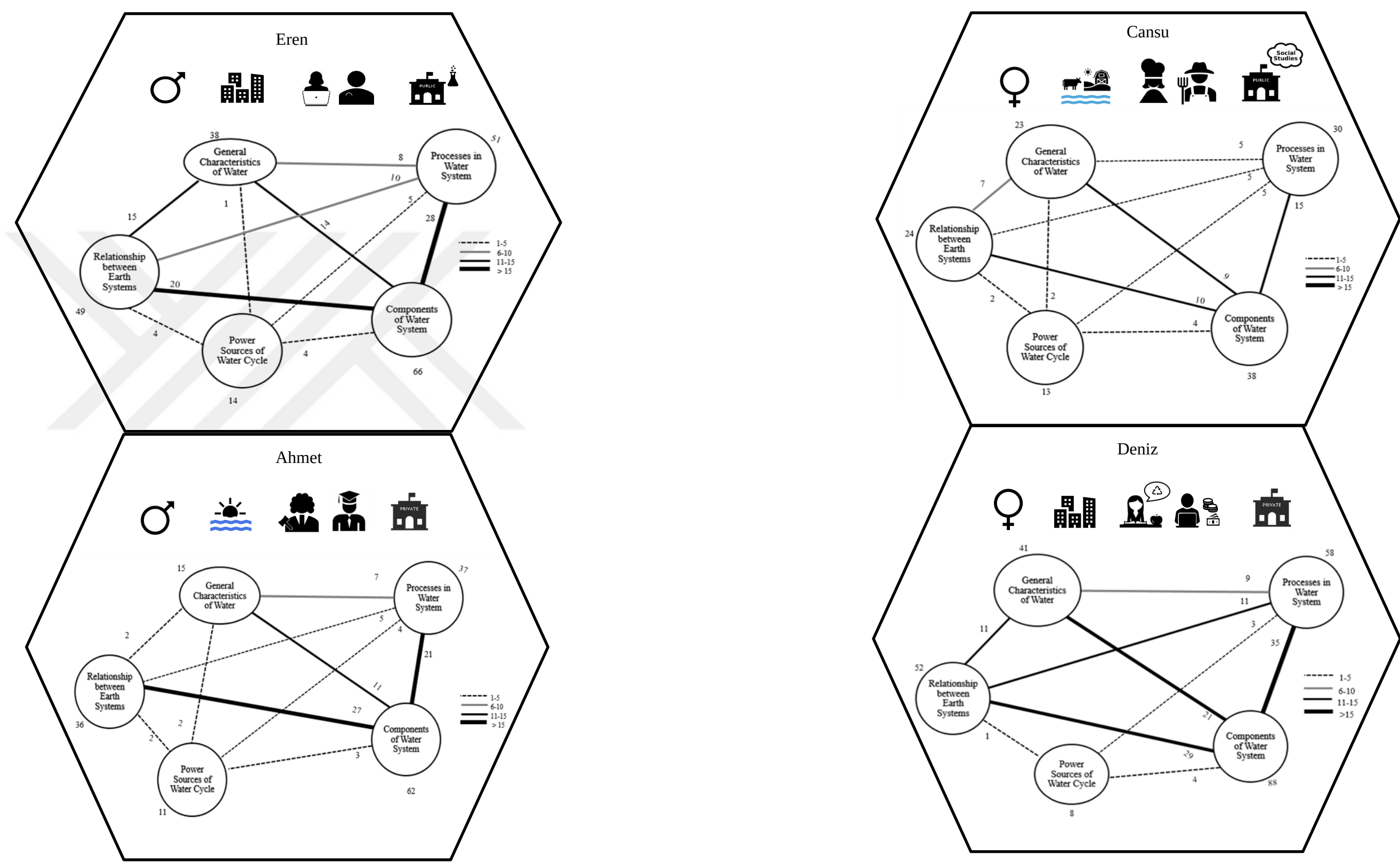
- The number of interactions of Eren and Deniz were higher than their peers. Cansu and Ahmet made weaker interactions while they were talking about the basics of the water system.
- *Components of Water System, Processes in Water System, and Relationship between the Earth Systems* had most interactive categories among the others.
- *Power Sources of the Water Cycle* was the most limited category among the others. There was a weak integration of the power sources into the other categories of FSL to explain the basics of the water system.
- The number of interactions between *Components of Water System- Processes in Water System* were higher in Eren, Cansu and Deniz's maps. Ahmet's most interactive categories were *Relationship between Earth Systems* and *Components of Water System*.
- Deniz did not make connection between *General Characteristics of Water* and *Power Sources of Water Cycle* while she was talking about the basics of the water system.





Figure 5.40

Comparison of Interactions among FSL of the Cases





### 5.3.5.1.1 Comparison of Conception Test Results, Alternative Conceptions and In-situ Answers

In this part, conception test results of the cases and their alternative conceptions were summarized. Answer key is available in Appendix A. Ahmet and Eren had eight fully correct responses, whereas Cansu had seven and Deniz had five fully correct responses. The questions related to proportion of water (Question 1), power sources (Question 2), and global warming (Question 9) were correctly selected by all four cases. In terms of alternative conceptions, all cases except Ahmet had alternative conceptions. In-situ responses, however, were detected in Eren and Deniz' responses. The list of alternative conceptions and in-situ responses were provided in Table 5.23. The questions that participants had lack of knowledge were cloud formation (Question 4) and climate change (Question 10). Additionally, Deniz had difficulty in selecting correct answers in Question 8 which was about gravity as a power source. provided all responses of the cases.

**Table 5-23**

List of Alternative Conceptions and In-Situ Responses Emerged in FSL

| Case  | Alternative Conception                                                                                                                                                                                                                                                                                 | In-situ Response                                                                                                                                                                                                                                                                                                 |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Eren  | <ul style="list-style-type: none"> <li>Water evaporating from the earth's surface goes to the clouds</li> </ul>                                                                                                                                                                                        | <ul style="list-style-type: none"> <li>The amount of water in the water cycle decreases because of water pollution</li> </ul>                                                                                                                                                                                    |
| Cansu | <ul style="list-style-type: none"> <li>The amount of water on Earth decreases</li> <li>The hole in the ozone layer leads to glacier melting and climate change</li> </ul>                                                                                                                              | No in-situ response was detected                                                                                                                                                                                                                                                                                 |
| Ahmet | No alternative conception was detected                                                                                                                                                                                                                                                                 | No in-situ response was detected                                                                                                                                                                                                                                                                                 |
| Deniz | <ul style="list-style-type: none"> <li>The amount of water on Earth increase and decrease in time</li> <li>Water molecules start to go up to the atmosphere when their weight become lighter (<i>heavier things sink</i>)</li> <li>Precipitations are the starting point of the water cycle</li> </ul> | <ul style="list-style-type: none"> <li>The largest amount of water could be groundwater resources</li> <li>Atmosphere is one of the power sources in the water cycle</li> <li>Plants are one of the power sources in the water cycle</li> <li>Streams are one of the power sources in the water cycle</li> </ul> |

**Table 5-24**

*Comparison of Conception Test Responses*

| AHMET                         |                                                  |   |   |   | EREN               |                               |                                                          |   |         |   |                        |
|-------------------------------|--------------------------------------------------|---|---|---|--------------------|-------------------------------|----------------------------------------------------------|---|---------|---|------------------------|
| Sub-question<br>Main Question | 1                                                | 2 | 3 | 4 | Status of Response | Sub-question<br>Main Question | 1                                                        | 2 | 3       | 4 | Status of Response     |
| 1                             | d                                                | a | a | a | Correct            | 1                             | d                                                        | b | a       | b | Correct                |
| 2                             | e                                                | b | b | a | Correct            | 2                             | e                                                        | a | b       | b | Correct                |
| 3                             | a                                                | b | a | a | Correct            | 3                             | a                                                        | a | a       | a | Correct                |
| 4                             | c                                                | c | d | c | Lack of Knowledge  | 4                             | a, c                                                     | b | a, d    | b | Lack of Knowledge      |
| 5                             | b                                                | b | d | b | Correct            | 5                             | b                                                        | a | d       | a | Correct                |
| 6                             | c                                                | a | b | b | Correct            | 6                             | a                                                        | b | a, c, d | b | Alternative Conception |
| 7                             | b                                                | b | c | a | Correct            | 7                             | b                                                        | a | c       | a | Correct                |
| 8                             | a                                                | a | a | a | Correct            | 8                             | a                                                        | a | a       | a | Correct                |
| 9                             | b                                                | a | b | a | Correct            | 9                             | b                                                        | b | b       | b | Correct                |
| 10                            | c                                                | b | e | b | False Negative     | 10                            | b                                                        | a | e       | a | Correct                |
| Total                         | 8 Correct, 1 Lack of Knowledge, 1 False Negative |   |   |   |                    | Total                         | 8 Correct, 1 Lack of Knowledge, 1 Alternative Conception |   |         |   |                        |

| CANSU                         |                                                          |   |      |   | DENİZ                  |                               |                                                          |   |   |   |                        |
|-------------------------------|----------------------------------------------------------|---|------|---|------------------------|-------------------------------|----------------------------------------------------------|---|---|---|------------------------|
| Sub-question<br>Main question | 1                                                        | 2 | 3    | 4 | Status of Response     | Sub-question<br>Main Question | 1                                                        | 2 | 3 | 4 | Status of Response     |
| 1                             | d                                                        | c | a    | b | Correct                | 1                             | d                                                        | c | a | c | Correct                |
| 2                             | e                                                        | a | b    | a | Correct                | 2                             | e                                                        | a | b | a | Correct                |
| 3                             | c                                                        | b | c, d | b | Alternative Conception | 3                             | d                                                        | b | b | a | Alternative Conception |
| 4                             | a                                                        | d | a    | c | Lack of Knowledge      | 4                             | a                                                        | a | b | a | Correct                |
| 5                             | b                                                        | a | d    | a | Correct                | 5                             | c                                                        | c | a | b | Alternative Conception |
| 6                             | c                                                        | c | b    | b | Correct                | 6                             | c                                                        | a | b | a | Correct                |
| 7                             | b                                                        | a | c    | a | Correct                | 7                             | a                                                        | b | b | a | Alternative Conception |
| 8                             | a                                                        | a | a    | a | Correct                | 8                             | c                                                        | c | c | b | Lack of Knowledge      |
| 9                             | b                                                        | c | b    | b | Correct                | 9                             | b                                                        | a | b | a | Correct                |
| 10                            | b                                                        | b | a    | c | Lack of Knowledge      | 10                            | c                                                        | a | e | c | Lack of Knowledge      |
| Total                         | 7 Correct, 2 Lack of Knowledge, 1 Alternative Conception |   |      |   |                        | Total                         | 5 Correct, 3 Alternative Conception, 2 Lack of Knowledge |   |   |   |                        |

### 5.3.5.2 Comparison of Cultural Systems Literacy across Cases

As stated in the previous section, the patterns of CUSL were traced through the second drawing task and interview questions of phase 2. The findings of within-case analyses revealed three categories in FSL as (1) components of local water system; (2) national water resources; and (3) relationships among local, national, and global systems. In addition, enumerative approach indicated the interactions among the categories of CUSL of a participant. In this part, comparison of each category and interaction maps were presented.

While examining the content of each category, both declarative and procedural knowledge were traced in case's responses which were summarized in [Table 5-25](#). In this theme, all of the cases except Cansu had limited amount of declarative and procedural knowledge compared to their FSL. Nevertheless, Cansu's background knowledge was mostly declarative, but still she had a richer understanding on her local water system compared to others.

In terms of components of local water system, the frequency of statements that included procedural knowledge were lower than declarative knowledge in all four cases. Specifically, Cansu had more fully correct statements in both declarative and procedural knowledge than the other three cases. Water supply network and sewerage system were the categories that participants had difficulty to express their understanding. All of the cases stated that they did not know the entire mechanism of water supply network and sewerage system. Except Cansu, they guessed the possible components and processes in WSN and sewerage system of their hometown. While they are making guess, they formed in-situ answers which were not mostly compatible with the actual situation.

Deniz was the cases talking about national water resources more than her local water system. Ahmet, on the other hand, mentioned both his local and national water system. Eren responded only the question about the status of water-richness of Turkey during

the interview. Unlike them, Cansu did not talk about national water resources, but she mentioned mostly the local water system in her hometown compared to her peers. In terms of relationship among the local, national, and global (sub)systems, all cases had more fully correct statements compared to other categories. Nevertheless, they had also alternative conceptions and in-situ answers. Among the cases, Deniz had difficulties to express the interactions among the local, national, and global (sub)systems.

Enumerative approach enabled to see the map of interactions among the categories of FSL of a case. [Figure 5.41](#) summarized the comparison of CUSL interaction maps of cases. The findings can be summarized as following:

- Interaction maps of CUSL were weaker than those of FSL. The number of interactions of Cansu were higher than her peers. Eren's responses produced weakest interaction map.
- *Relationship between the Local, National and Global Systems* had most interactive categories among the others.
- *Local Water Resources, National Water Resources, and Processes in WSN* produced relatively weaker interactions among the others. There was a weak integration of these categories of CUSL to explain the basics of the local water system.
- The highest number of interactions between categories with respect to cases were following:
  - Cansu:
    - (1) Relationship between the Local, National and Global Systems - Components in WSN;
    - (2) Relationship between the Local, National and Global Systems - Components of Local Water System; and
    - (3) Relationship between the Local, National and Global Systems – Local Water Resources
  - Ahmet: Components of Local Water System- Local Water Resources
  - Deniz: Components in WSN – Processes in WSN
- Cansu did not make connection between *National Water resources* and other categories while she was talking about the basics of the water system.

**Table 5-25**

*Frequency Table of Comparative Analysis of CUSL*

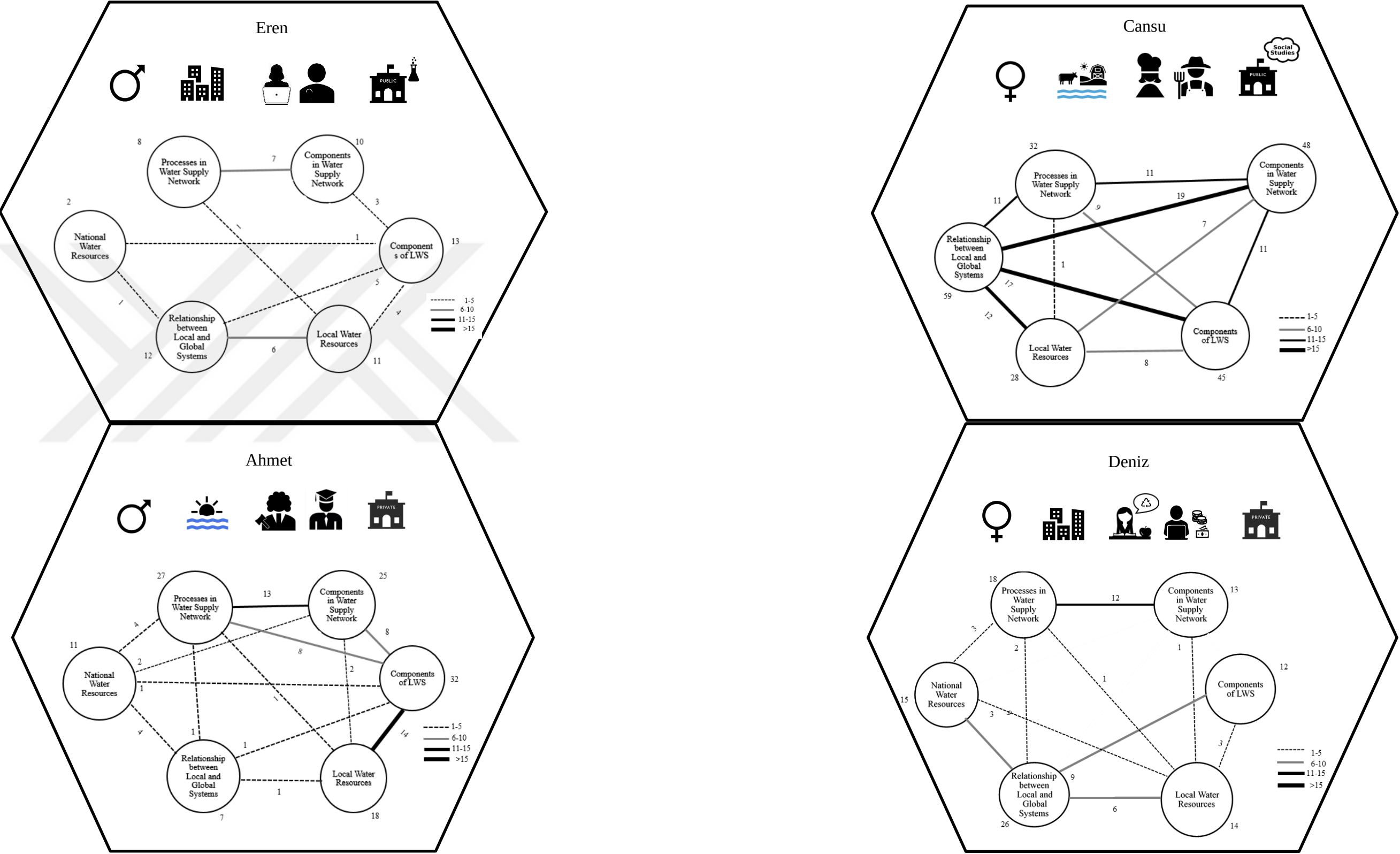
| Category of FSL                                    | Case  | Fully Correct Statement(s)    |                              |                                         | Partially Correct Statement(s) |                              |                                         | Incorrect Statement(s)        |                              |                                         | Don't know (n <sub>7</sub> ) |
|----------------------------------------------------|-------|-------------------------------|------------------------------|-----------------------------------------|--------------------------------|------------------------------|-----------------------------------------|-------------------------------|------------------------------|-----------------------------------------|------------------------------|
|                                                    |       | Declarative (n <sub>1</sub> ) | Procedural (n <sub>2</sub> ) | Total (n <sub>1</sub> +n <sub>2</sub> ) | Declarative (n <sub>3</sub> )  | Procedural (n <sub>4</sub> ) | Total (n <sub>3</sub> +n <sub>4</sub> ) | Declarative (n <sub>5</sub> ) | Procedural (n <sub>6</sub> ) | Total (n <sub>5</sub> +n <sub>6</sub> ) |                              |
| Components of Local Water System and LWR           | Eren  | 1                             | -                            | 1                                       | 2                              | 1                            | 3                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Cansu | 3                             | 1                            | 4                                       | -                              | -                            | 0                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Ahmet | 1                             | 1                            | 2                                       | 2                              | -                            | 2                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Deniz | 1                             | -                            | 1                                       | 2                              | -                            | 2                                       | -                             | -                            | -                                       | -                            |
| Water Supply Network and Sewerage System           | Eren  | 2                             | -                            | 2                                       | 1                              | 2                            | 3                                       | 2                             | 3                            | 5                                       | 3                            |
|                                                    | Cansu | 3                             | 1                            | 4                                       | 2                              | 2                            | 4                                       | -                             | -                            | 0                                       | 3                            |
|                                                    | Ahmet | 2                             | -                            | 2                                       | 3                              | 2                            | 5                                       | 2                             | 2                            | 4                                       | 2                            |
|                                                    | Deniz | 2                             | -                            | 2                                       | 2                              | 2                            | 4                                       | 1                             | 2                            | 3                                       | 5                            |
| National Water Resources                           | Eren  | 1                             | -                            | 1                                       | -                              | -                            | 0                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Cansu | -                             | -                            | 0                                       | -                              | -                            | 0                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Ahmet | 1                             | -                            | 1                                       | -                              | -                            | 0                                       | -                             | -                            | 0                                       | -                            |
|                                                    | Deniz | 3                             | -                            | 3                                       | -                              | -                            | 0                                       | -                             | 1                            | 1                                       | -                            |
| Relationship between Local and Global (Sub)systems | Eren  | 3                             | -                            | 4                                       | 1                              | 2                            | 3                                       | -                             | 1                            | 1                                       | -                            |
|                                                    | Cansu | 1                             | 1                            | 5                                       | 1                              | 2                            | 3                                       | -                             | 2                            | 2                                       | -                            |
|                                                    | Ahmet | 4                             | 1                            | 5                                       | 1                              | 2                            | 3                                       | 1                             | -                            | 0                                       | -                            |
|                                                    | Deniz | 2                             | -                            | 2                                       | 2                              | 2                            | 4                                       | 1                             | 2                            | 3                                       | -                            |





Figure 15.41

Comparison of Interactions among CUSL of the Cases





#### 5.3.5.2.1 List of In-situ Responses in Cultural Systems Literacy

In this part, *in-situ* responses of the cases were summarized. All cases except Cansu had in-situ responses. The list of in-situ responses was given in [Table 5-26](#).

**Table 5-26**

*List of In-Situ Responses Emerged in CUSL*

| Case  | In-situ Response                                                                                                                                                                                                                                                                                                               |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Eren  | <ul style="list-style-type: none"><li>• Water may be treated before the distribution to our homes if it is hardwater</li><li>• Our tapwater is coming from the groundwater resource</li><li>• The expenditure of treating the wastewater would be so high that it is not feasible to be provided by the governments.</li></ul> |
| Cansu | No in-situ response was detected                                                                                                                                                                                                                                                                                               |
| Ahmet | <ul style="list-style-type: none"><li>• Rainwater accumulates the dams</li><li>• Wastewater could be discharged to another dam to retreat and reuse it again</li></ul>                                                                                                                                                         |
| Deniz | <ul style="list-style-type: none"><li>• Precipitations accumulate the dams</li><li>• Domestic wastewater might be recycled, bottled, and sold us again.</li></ul>                                                                                                                                                              |

#### 5.3.5.3 Comparison of Critical Systems Literacy across Cases

As stated in the previous section, the patterns of CRSL were traced through the interview questions of phase 3 and phase 4. The findings of within-case analyses revealed two themes in CRSL as (1) advance mechanisms of water system; and (2) invisible elements of human systems. These two themes had several categories and comparison of each category were presented in this section.

##### 5.3.5.3.1 Advance Mechanisms of Water System

This theme had four categories as (1) Dynamic nature of the water system; (2) Causal dynamics and feedback loops; (3) Evolutionary processes in water system; and (4) Complexity of the water system. The comparison of the cases in each category was summarized in this part.

### *Dynamic Nature of the Water System*

This category was traced through the concept of unconscious use of water and its dynamic effects on the water system. All four cases were aware of the time delays in the water system, however they failed to elaborate the possible reasons and dynamic effects of time delays in water system. For instance, while Deniz and Ahmet attributed time delays to overpopulation, Eren and Ahmet mentioned the effects of water pollution on the time delays in the water system. Cansu only stated that it is required a long time to recover the negative effects on the water system, but she failed to elaborate these effects and recovery period. In terms of redistribution of the water, Eren and Ahmet emphasized the role of global warming and climate change on redistribution of water. On the other hand, Cansu and Deniz had statements that were indicators of lack of dynamic conceptions. While Cansu mentioned that groundwater resources remained below the surface and cannot be used, Deniz stated that water precipitates where it evaporates. These statements were indicators that they failed to consider groundwater, precipitation and evaporation as dynamic concepts, but rather static. Additionally, all participants had some in-situ answers that they could not able to transfer them into other context and alternative conceptions as well. Since Cansu and Deniz did not know that the total volume of water is almost constant on Earth, they tried to explain dynamical mismatches based on this alternative conception.

### *Casual Dynamics and Feedback Loops*

Causal dynamics and feedback loops were emerged during the interviews. All four cases mentioned a reinforcing loop in their responses in an implicit manner. In other words, while they were talking about causalities, their responses formed a reinforcing loop, but they did not name this loop as a reinforcing loop. Except Cansu, all three cases revealed at least an open loop with multiple causalities. Among the cases, only Ahmet's responses indicated balancing loops.

### *Evolutionary Processes in Water System*

Evolutionary process in water system was asked in the interview part which was about their predictions for the future scenarios of local, national, and global water system. While Cansu and Deniz argued that the water system is a decaying state, Eren claimed that the water system will be steady state in the near future. Ahmet, on the other hand, gave different possible scenarios for the future scenarios for different countries. He discussed that when the water system is decaying, evolutionary state of the countries would compensate and it would differ according to their developmental state (i.e., underdeveloped, developed). Whereas some developed countries achieved to keep their water system steady state, underdeveloped countries had possibility to be in a decaying state.

### *Complexity of the Water System*

Within the context of the water system, the issue of climate change and hidden use of water were included as two of the interruptions in the water system and possess many layers of complexity such as economic, social, environmental, educational, health, and governmental layers. The comparison of cases' responses revealed that all four cases were able to detect interruptions as global warming and climate change given in the real story in interview phase 4. While Eren and Ahmet provided procedural knowledge on the mechanisms of global warming and climate change, Cansu and Deniz failed to reveal their procedural knowledge on these interruptions. Additionally, Ahmet revealed some misconceptions related to global warming and ozone layer depletion. In terms of layers of complexities, all cases reported environmental and social layers of complexities. Ahmet and Deniz mentioned also economic and health layers, while Eren was talking about economic effects of interruptions in addition to environmental and social effects. Eren and Deniz have never heard about the term "hidden use of water", whereas Ahmet and Cansu reported that they learned the term from extracurricular activities. Even though Eren and Deniz were not familiar with the term, they were able to infer some processes in which water is spent for a product, in our

case, hamburger. Nevertheless, they failed to indicate packaging processes and wastewater that spent to produce a hamburger. Cansu and Ahmet, on the other hand, were aware of that too much water is spent to produce a hamburger compared to daily direct use of water. Similar with Eren, they also failed to mention animal's grain, packaging processes and wastewater to produce a hamburger. Only Deniz were able to state that water is spent to animal's grains in hamburger's water footprint. Last, all the cases except Deniz reported that consumers were responsible for the water consumption to produce a hamburger. Deniz argued that the people serving in the production phases were responsible for the water consumption.

#### **5.3.5.3.2 Invisible Elements of Human System**

Invisible elements of human system as a second theme in critical systems literacy involves the categories of beliefs about water use, action strategies for efficient water use, self-efficacy beliefs towards efficient water use, emotional responses, motive concerns, and motivational orientation for sustainable water use.

##### *Beliefs on Self-Use and Collective Use of Water*

All cases shared their beliefs on their self-use of water as well as collective use of water. They reflected their descriptive, inferential, and informational beliefs on their water consumption. [Table 5-27](#) summarized their belief statements with their type of beliefs.

Table 5-27

*List of Belief Statements*

| Case  | Types of Beliefs        |               | Belief Statements                                                                                                      |
|-------|-------------------------|---------------|------------------------------------------------------------------------------------------------------------------------|
| Eren  | Self-Use of Water       | Descriptive   | - I try not to waste it while I am using it. I hope I am not doing it.                                                 |
|       | Collective Use of Water | Inferential   | - The rate of wasting water is increasing in these days                                                                |
| Cansu |                         | Informational | - People have positive effects on the water system in terms of environmental aspect                                    |
|       |                         |               | - People have negative effects on the water system in terms of (a) environmental, (b) economic, and (c) social aspects |
|       |                         |               | - I used water efficiently most of the time                                                                            |
|       | Self-Use of Water       | Inferential   | - I am one of the responsible water users                                                                              |
|       |                         |               | - I am more conscious than other people                                                                                |
|       |                         |               | - I am in the middle of the water system                                                                               |
| Ahmet | Collective Use of Water |               | - People use water inefficiently                                                                                       |
|       |                         |               | - People will not take lesson continue to consume water inefficiently                                                  |
|       |                         |               | - I have no effect on the water system                                                                                 |
| Deniz |                         | Inferential   | - Older people have negative effects on the water system                                                               |
|       |                         |               | - Older people have more water consumption rate than me                                                                |
|       |                         |               | - I am a conscious consumer of water                                                                                   |
|       | Self-Use of Water       | Inferential   | - I am not responsible for the water consumption in agricultural and industrial farming.                               |
|       |                         |               | - I am more conscious than other people in terms of efficient water use                                                |
|       |                         |               | - We are in the middle of the water system                                                                             |
|       | Collective Use of Water |               | - People are one of the factors affecting the water system and                                                         |
|       |                         |               | - People have negative effect for this system.                                                                         |

### *Action Strategies for Efficient/Sustainable Water Use*

Ahmet reported no specific action strategies related to his water consumption behavior. The other three cases reported some action strategies related to their direct use of water. Among them, only Cansu mentioned action strategies for monitoring her hidden use of water. In terms of direct use of water, Cansu and Deniz provided detailed information on how to reduce their water consumption in their daily life. Eren did not prefer to explain them in detail but summarized his water efficiency behaviors as doing the ‘cliché’. Moreover, Eren and Cansu also exemplified the role of persuasion of other people to invite them use water efficiently.

### *Self-Efficacy Beliefs toward Efficient Water Use*

This part was not observed in Ahmet and Eren’s responses. However, Cansu and Deniz showed some indicators that can be considered as high self-efficacy. Both stated that they use water efficiently most of the time and they know how to water use efficiently.

### *Emotional Responses, Motive Concerns and Motivational Orientation*

Every case in this study revealed unique combinations of emotional responses related to their self-water use and other people’s water consumption behavior. Eren explained that he would be angry when he sees people wasting water and happy when people tried to use water efficiently. Cansu reported that she would sad to see when the water is used inefficiently. She also stated that she is proud of her family and herself because they reduce their water use and do recycling whenever possible. Deniz shared her sadness whenever she sees inefficient use of water. On the other hand, Ahmet reflected his apathy to regulating and monitoring his water consumption behavior. All cases reflected the two motive concerns as social altruistic and biospheric. However, the dominant one in responses was social altruistic except Deniz’s responses. Deniz had no dominant motive concern and she mentioned the importance of water for both living organisms and human beings. In terms of motivational orientation, all cases except



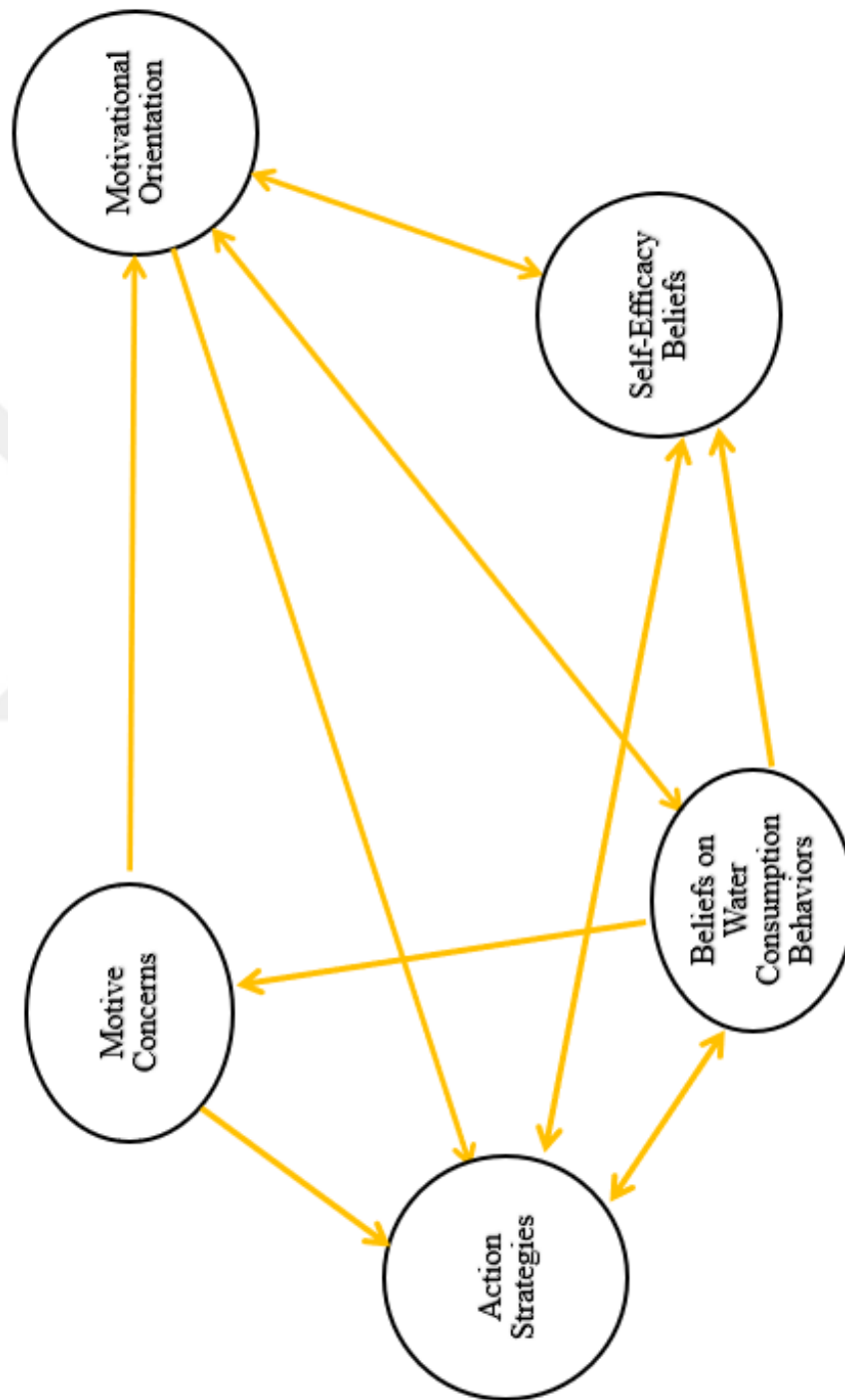
Ahmet revealed extrinsic motivational orientation towards efficient water use. Ahmet had amotivation and did not have specific goal for using water efficiently.

#### **5.3.5.3.3 Interaction Web among the Elements of Human System**

In this part, an interaction web was produced based on the responses of the cases. The direction of the arrows indicated the direction of the relationships. This interaction web was not case-specific but represented the flow of their responses during the data collection. For example, when they talked about their motivational orientation, they attributed their water consumption behavior to their motive concern. For this interaction, an arrow was put from motive concern to motivational orientation. These interactions were provided in [Figure 5.42](#).

**Figure 5.42**

*Interaction Web Among the Categories Human System*



#### **5.4 Possible Factors Interfering with Systems Literacy**

Within the context of the study, several factors were examined whether they interact with the three elements of systems literacy or not. These factors were as gender, daily life experiences, cognitive differences, socioeconomic status indicators, residence area, and parental interactions. In this part, they were reported in detail.

In terms of gender, several differences detected. When FSL of the cases were compared in terms of gender, boys had richer understanding on the basics of the water system in FSL. In terms of CUSL, however, no specific differences were detected between genders. On the other hand, the interactions with critical systems literacy was behaved differently in two themes. The first theme of CRSL was about the advance mechanisms of water system and boys had richer understanding compared to girls even if their understanding was limited. On the other hand, the findings of the second theme were quite opposite compared with the first one. Even though girls had limited amount of knowledge in FSL and Deniz further had limited amount of CUSL, girls were more motivated than boys for using water efficiently; have more detailed action strategies accompanied with high self-efficacy beliefs. Moreover, they were more concerned about the water system and had more intensive emotional responses than boys.

Cognitive difference was another variable that interacted with systems literacy of the cases. Within the context of the study, FSL covered natural science concepts, while CUSL and CRSL included both natural science and social science concepts. When we compare our findings in FSL, no clear distinction was observed in our cases. Except Deniz, all three cases had similar number of correct responses in the conception test. In frequency table of comparative analysis of FSL, Ahmet and Eren had more fully correct statements than Deniz and Cansu. Both conception test and comparative analysis formed a similar pattern with their national exam scores or their level of achievement. From this perspective, their FSL and level of achievement were directly proportional to each other. However, when we delve into the responses in terms of declarative/procedural knowledge and alternative conceptions, all participants had

more declarative knowledge than their procedural knowledge. Among the participants, Cansu had the ones that had least fully correct declarative knowledge statements than others. In terms of procedural knowledge, Cansu had no fully correct statements. Nonetheless, Deniz had the ones that had more incorrect statements and alternative conceptions than others in FSL. In CUSL, the situation was different. In this element of SL, Cansu and Ahmet had more fully correct statements than Deniz and Eren. Among the participants, Deniz had the ones that had least fully correct declarative knowledge statements than others. In terms of procedural knowledge, Eren and Deniz had no fully correct statements. In a similar manner, they were the ones that had more incorrect statements and in-situ answers than others. In short, the premise of “cognitive difference could be a factor that interact students’ conceptions on water” was only for declarative knowledge in FSL.

Residence area in terms of including a body of water (e.g. seashore, riverside, inland) was another factor to be explored. In this study, Ahmet and Cansu live in waterfront areas, where Eren and Deniz were residences of metropolitan areas. In conception test, Cansu, who lives in a rural area, did not bring up the rear. However, she had lower scores than her peers in comparative analysis as well as in procedural knowledge in FSL. Nonetheless, she performed better than her urban peers while she was explaining the basics of her local system (CUSL). In a similar manner, Ahmet who lives in seashore had richer understanding in terms of both FSL and CUSL. To recap, Ahmet and Cansu had richer understanding on the basics of the water system and provided more detail on water system in their hometown.

As provided in the methodology chapter, parental occupation is one of the indicators for socioeconomic status of a family (Aarø et al., 2009; Galobardes et al., 2006) and socioeconomic status is positively correlated with child’s academic achievement in Turkey (MoNE, 2018). The parental occupations of Ahmet and Eren, who are high achievers, were one of the indicators for high socioeconomic status. Within the context of the study, FSL is found to be compatible with students’ achievement scores since FSL encompasses concepts that is taught in school context. The findings revealed that

Eren and Ahmet had a richer understanding in FSL and advance mechanisms in CRSL compared to other cases.

Parental interactions were found to interfered with participants' CUSL and invisible elements of human system in CRSL. For example, the analysis of responses revealed that the interactions of Cansu and Deniz with their parents interfered with their CUSL and CRSL. For example, Cansu had relatively richer CUSL compared to other cases. When her responses were examined, she mentioned her activities in their garden done with her father. Moreover, she also had more developed motivational orientation, motive concerns, action strategies and self-efficacy beliefs than her peers in this study. In a similar manner, Deniz, whose mother was an environmental educator, had responses in CRSL that revealed her interactions with her mother such as in her motivational orientation, motive concerns, action strategies, and self-efficacy beliefs.

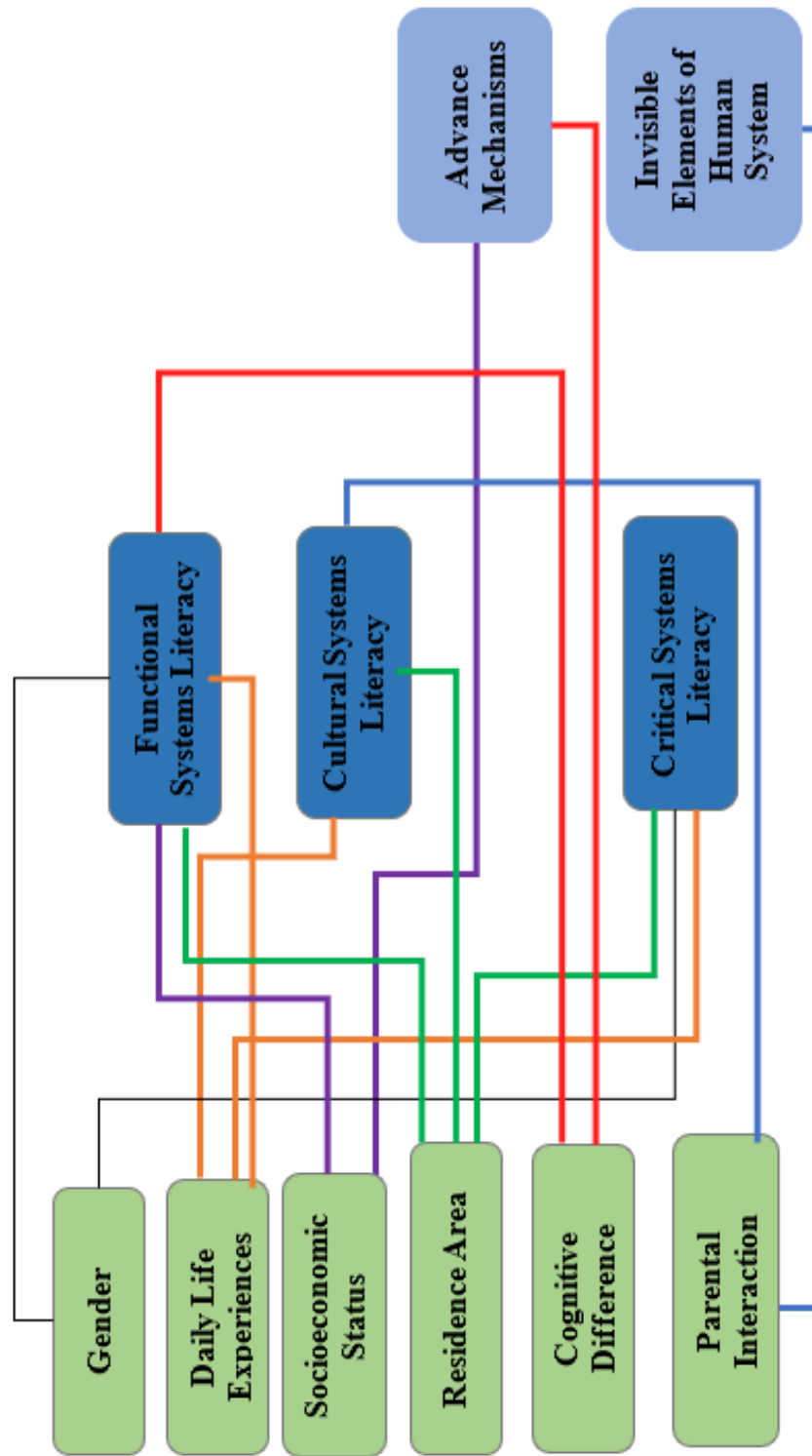
Another variable, types of high school, was not detected as a factor that interact with students' systems literacy. Instead, participation of extracurricular activities offered by the high school and daily life experiences were found to have interactions with students' systems literacy. For instance, Eren attended seminars of systems science and sustainable development goals. His participation to extracurricular activities was shown in his responses in FSL but no indicator was found in his responses in CUSL and CRSL. On the other hand, Cansu attended waste collection event in her village and a water footprint seminar offered by her high school. The instances from her participation were apparent her declarative knowledge in FUSL, declarative and procedural knowledge in CUSL. Ahmet, on the other hand, watched videos related to water issues in Turkey and water footprint. These extracurricular media were apparent in his declarative knowledge on FSL. Nonetheless, he stated that he did not integrate this knowledge into his action strategies in his daily life. Deniz exemplified instances from her vacations as well as popular news on the media while she was talking about the basics of her local system.

Even though all cases exemplified some of the instances from media and internet and these variables interacted with their FSL, no specific instance was detected that reflect in their CRSL. For example, Ahmet correctly explained the concept of hidden use of water but his responses in CRSL revealed that he did not integrate this concept into water consumption behavior. What is more, he was amotivated towards efficient water use.

The analysis of the responses revealed that some of the in-situ answers and alternative conceptions were based on cases' observations and daily life observations. For example, Cansu stated that the water is not used anymore after penetrating the soil. This alternative conception was based on her daily life observation in her garden. She exemplified discharged wastewater from her home to the garden penetrated to the soil and it is not available anymore. On the other hand, daily life experiences were also apparent in their responses related to CRSL. They constructed causalities and feedback loops based on their experiences. Moreover, they formed beliefs on both individual and collective use of water based on the observations of other people's daily water consumption behaviors. These responses and sample excerpts were given in within-case analyses. The summary of these variables and their interactions with three elements of systems literacy was visualized in Figure 5.43.

**Figure 5.43**

*Possible Factors Interfered with System Literacy in Water Context*



## **CHAPTER 6**

### **DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS**

The purposes of this study were to provide a conceptual model for the description of 'systems literacy'; propose an alternative framework for the elements of systems literacy in water system context; explore possible factors that might interfere with systems literacy in water system context; and determine readiness of children completing middle school degree in terms of systems literacy in water system context. In this section, discussions, conclusions, and implications were made based on the related literature as well as the findings of the present study.

#### **6.1 What is Systems Literacy?**

One of the aims of the present study was to suggest an alternative framework for systems literacy. In the light of the evolution of systems, systems thinking, and systems literacy contexts, the debates on literacy definitions, the effects of milestones and 21<sup>st</sup> century global issues, and gaps in the literature, the researcher intended to offer an alternative definition for systems literacy compatible with the literature on systems and systems thinking as well as the definition of traditional literacy itself. By collecting data in a specific system, the water system, the researcher tested and assessed her definition for systems literacy.

Framing a definition for systems literacy was a challenging process since different approaches for systems (e.g., Checkland, & Holwell, 1998), systems science (e.g. Hieronymi, 2013), systems thinking (Henning & Chen, 2012), and systems literacy (e.g. Reynolds, 2011; Sweeney, 2012) are available in different disciplines (e.g. business management, computer engineering, education). Every description as well as its scope brought its own valuable contribution as well as its limitation. Additionally, there are a limited number of studies describing the notion of systems literacy (e.g.



Reynolds, 2011; Sweeney; 2012; Tuddenham, 2017; Wood; 2012) and most of them emphasized ‘what to know’ about the systems and determined some skills needed for systems literacy. What is more, current systems thinking studies did not embrace all of the general principles of systems science which might be considered as a drawback since I believe that systems thinking should not be defined based on some of the principles of systems science. Therefore, tailoring these concepts to delineate systems literacy within the context of education and overcoming some of their limitations of previous studies needed a certain amount of effort. Correspondingly, the researcher of this study chose a path as follows:

- Select a theoretical framework for general principles for a ‘system’
- Take into account the common characteristics of ‘systems thinking’
- Consider keeping general characteristics of ‘literacy’
- Integrate these concepts to form ‘systems literacy’
- Test the notion of systems literacy within the context of water system

As an output of the theoretical research and analyzing them in a critical manner, systems literacy is defined by the researcher intending to provide an insight to reconsider the place of systems and systems thinking in science education as well as in education for sustainability (ESD).

Adhering to the definition of literacy (Stables & Bishop, 2001) and general principles of systems science (Mobus & Kalton, 2015), I constructed the notion of systems literacy in three elements as functional, cultural, and critical systems literacy. Currently available definitions for systems literacy was mainly dealt with necessary knowledge and skills (e.g. Reynolds, 2011; Sweeney; 2012; Wood; 2012) of the individuals which could be regarded under the section of functional systems literacy or ‘advance mechanisms of the systems’ in critical systems literacy that defined within the context of present study. One exception was the study of Wood (2012) focusing on the cultural perspectives in a system. However, being systems literate should be beyond the knowledge of the working principles of the systems and one could be able to blend his/her knowledge on the basics of the system in both global and local scale

to cultivate their critical systems literacy. As Stables (1998) emphasized, having merely functional and cultural literacy makes no sense unless critical literacy is present. In a similar manner, including these three elements to the definition of systems literacy is indispensable since critical systems literacy have a critical role in enabling individuals grasp the advance mechanisms of the systems as well as invisible elements of human system.

I revised these three elements by adding unique characteristics which might be also applicable to other future systems literacy studies. For instance, I tailored Marzano and Kendall's (2008) descriptions for different types of knowledge and Taber's 'The Inclusive View' model (2008) to the functional systems literacy for two reasons. First, based on my academic background, I would like to differentiate the types of knowledge of the students as declarative and procedural knowledge to amplify their FSL. There are different arguments available in the studies of systems thinking regarding the place of declarative and procedural knowledge. While Ossimitz (2000) claimed that procedural knowledge is essential for system thinking, Riess and Mischo (2010) contended the idea that declarative knowledge is important in systems thinking studies. On the other hand, after conducting a 6-years-later follow-up study, Ben-Zvi-Assaraf and Orion (2010a) concluded that declarative and procedural knowledge were inseparable constructs in systems thinking. Even though Ben-Zvi-Assaraf and Orion did not provide definitions for declarative and procedural knowledge, I agree with them with minor differences. Instead of inseparable constructs, declarative knowledge could rather be considered as a prerequisite for procedural knowledge, as Marzano and Kendall (2008) also highlighted. Thus, for being deemed to be a functionally systems literate, I would like to place equal importance for both declarative and procedural knowledge. Second, I also chose to delve into incorrect responses of the participants by using Taber's approach to discriminate them in terms of being stable or labile. This enabled me to examine whether their incorrect responses were formed during the data collection or based on stable and consistent alternative conceptions. As Taber (2008) emphasized, differentiating these incorrect responses could guide us how to reorient

our teaching to provide a fruitful learning to the students. Within the context of systems literacy, determining the nature of students' incorrect responses could be one of the initial steps for removing the obstacles in becoming systems-literate. To recap, differentiating the types of knowledge as well as examining incorrect responses in-depth might be considered as two unique characteristics for exploring individuals' functional systems literacy.

Cultural systems literacy was another section in the systems literacy which has also its own characteristics. As stated in the previous chapters, systems have subsystems or models within the systems itself. In a similar manner, systems have also subsystems or model in local areas of the individuals. What is more, some systems might be attributed to special meaning compared to others in a culture. Therefore, examining individuals' mental models on the basics of their local systems could provide us another point of view within the context of systems literacy. Additionally, individuals' CUSL has intersection set with one's FSL at some points and CUSL provides also basis for cultivating one's critical systems literacy. The findings of the present study revealed that individuals could not be able to transfer their FSL to CUSL context. Moreover, their alternative conceptions and in-situ responses distorted their mental models of their cultural context and this also hindered individuals' critical systems literacy. Based on the reasons given above, a special section for cultural systems literacy might be useful within the systems literacy. Because of the same reasons that I summarized for FSL, I integrated types of knowledge and Taber' inclusive model for incorrect responses into the notion of CUSL. Examining their declarative and procedural knowledge as well as understanding the nature their incorrect responses in cultural context might also pave the way for us to raise system-literate individuals.

Critical systems literacy could be considered as the tender spot of systems literacy since it involves constructs to grasp advance mechanisms of the system and to develop a personal and social response to maintain the mechanisms of the system. Functional and cultural systems literacy and their interactions also provide a basis for cultivating critical systems literacy. If individuals did not perceive the system and the role of

individual and collective behavior in that system, it will not be possible to name them as systems-literature individuals. Within the context of this study, I accommodated the content of the CRSL based on the pilot study and previous works available in the literature. I divided CRSL into two themes as ‘advance mechanism of the system’ and ‘invisible elements of human system’. The former theme was constructed based on the studies of Mobus and Kalton (2015), Sweeney (2012), and Ben-Zvi-Assaraf (2005b). I made several revisions and provided a discussion in the next sections of this chapter. The latter theme was added several constructs based on the works of Henning and Chen (2012) and Marzano and Kendall (2008).

The literature on systems literacy is growing since the beginning of 00’s. Even though I tried to review them and provide a reconsolidated definition from the perspective of a social scientist, whose research interest is science education, this area can be considered as intact to be explored. Of course, there could be some additional constructs in CRSL. Even more, some of the constructs might not be significant or might have different portion of contributions in other contexts. Thus, future systems literacy researchers should bear in mind these possibilities. to understand the nature of systems literacy.

### **6.1.1 Systems Literacy in Water Context**

The general principles of systems science were guided to describe systems literacy in this study. Moreover, these principles were used to describe the notion of systems literacy within the context of water system. As stated in the introduction chapter, Turkish students do not also expose to a systems literacy embedded courses, it would not be compatible to conduct an explicit study on systems and systems literacy. Also, an explicit study whose aim is to understand students’ conceptions on systems may be too general since every system has its own dynamics (Schaefer, 1989; Mobus & Kalton, 2015). Besides, these principles were taken from a university textbook; thus, asking them directly to middle school students may not be suitable to their grade level. For these reasons, an implicit study choosing a familiar system was planned to be

conducted in which students are actively involved. Accordingly, water system on Earth was selected as a system since it is intended to explore middle school students' level of systems literacy by examining their water conception and water consumption behaviors.

Before passing to the next section, I would like to mention the previous studies related to water literacy. Even though there was no specific study for systems literacy in water context in the accessible literature, there were some studies focusing on water literacy. One of the first pronunciations of the term 'water literacy' in the functional literacy context was traced in the works of Ewing and Mills (1994). Covitt and her colleagues (2009), on the other hand, built a curricular framework for promoting water science literacy and they specifically interested in 'understandings necessary for reasoning about water in natural and human-engineered water systems' which might be considered within the context of FSL and CUSL. Wood (2014) conducted a dissertation on water literacy and citizenship within the context of ESD in UK. She described being water literate as following: "I suggest that a water literate citizen is someone who is informed and knowledgeable about water use and issues and is applying this knowledge to their values and their actions, whether that is achieved actively or subconsciously." (Wood, 2014, p. 7). All these studies included valuable indicators for functional, cultural, and critical systems literacy of the students in water context. Among these studies, alternative version of systems literacy in this study was compatible with the description of Wood (2014), although there are contextual differences.

In the light of definition of systems literacy given in the previous section, the content of the middle school curricula pertinent to water concepts and principles of systems science, systems literacy of middle school students within the context of the water system were described by the researcher. Based on this description, three elements of systems literacy in water system context were elaborated. As stated in the previous section, I am fully aware of the fact that there could be other different constructional combinations for the notion of systems literacy. These reconsolidated definitions were

derived from the outputs of a conceptual research and written from the perspective of a social scientist; whose research interest is science education. Thus, future systems literacy researchers should also provide their reflexivity statements in their studies to improve the literature on systems literacy. In the next part, middle school students' systems literacy in water context was discussed.

## **6.2 Middle School Students' Systems Literacy in Water Context**

### **6.2.1 Functional Systems Literacy**

The findings of within-case analyses revealed five categories in FSL as (1) general characteristics of water; (2) power sources of water cycle; (3) components of water cycle; (4) processes of water cycle and (5) relationship between the Earth systems. Students' responses in these five categories were classified as fully correct statements, partially correct statements, and incorrect statements. Correct statements were further labelled as declarative and procedural knowledge, while incorrect statements were elaborated as alternative conceptions and in-situ answers. Moreover, enumerative approach enabled me to see the interactions among the categories of FSL. Cross-case findings, on the other hand, invited us to see similarities and differences among the cases. To be reader friendly, I firstly discussed the issues of declarative/procedural knowledge and alternative conceptions/in-situ answers through providing the previous findings in the literature. Then, I provided a discussion for each category and interaction maps as well.

Knowledge is one of the mostly included components of the literacy studies. Extensive number of studies in the literature (e.g., Ben-Zvi Assaraf & Orion, 2010; Dutton, 2015; Schaffer, 2013) assessed the level of knowledge of the individuals and/or its interrelationships with other components of the literacy contexts. When the instruments with which the level of knowledge of the individuals was examined, almost all the instruments (e.g., Dutton, 2015; Schaffer, 2013) were used the first three levels of Bloom Taxonomy as *knowledge*, *comprehension* and *application*. For the higher order level thinking levels, few studies dealt with assessing those (e.g.

Marcinkowski et al., 2013). In short, these studies cover factual and/or conceptual knowledge, which only require rote memorization. These types of knowledge may not reflect the actual level of knowledge of individuals since they discard procedural knowledge which means that “*how to do something, methods of inquiry, and criteria focusing skills, algorithms, techniques, and methods*” (Anderson et al., 2001, p. 29). Thus, procedural knowledge was added to the context of this study.

The findings of this study revealed that all cases had more correct declarative knowledge than procedural ones. This is not surprising because there are similar results reported in the literature (e.g., Ben-Zvi-Assaraf & Orion, 2005a; 2005b; Dickerson & Dawkins, 2004; Havu-Nuutinen, Kärkkäinen, and Keinonen, 2018). They all agreed the idea that majority of children do not learn the meanings of scientific terms in depth; have naïve conceptions; have lack of understanding about how water cycles; and they are mostly declarative.

In terms of alternative conceptions, majority of K-12 studies on water reported alternative conceptions/misconceptions (Bar, 1989; Havu-Nuutinen, Kärkkäinen, & Keinonen, 2018; Henriques, 2002; Shepardson et al. 2011). Even though they did not name some of them as “in-situ answers”, these types of responses were also diagnosed in students’ responses (Covitt, et al., 2012). Henriques (2002) categorized alternative conceptions on water in the literature as (1) properties of water; (2) phase changes; (3) water cycle; (4) cloud formation and precipitation; (5) the atmosphere; (6) greenhouse effect/global warming; and (7) differentiation of the terms weather and climate. In our study, all cases except Ahmet revealed some of the categories while they were explaining the basics of the water system (see [Table 5.23](#)). For example, Eren revealed his alternative conception on cloud formation; Cansu had alternative conception on greenhouse effect/global warming and water cycle; and Deniz had alternative conceptions on water cycle and phase changes (evaporation).

The category of ‘general characteristics of water’ was composed of several subcategories as (1) quantity of water; (2) cyclic nature; (3) properties of water; (4)

water and living organisms; and (5) relational responsiveness. Quantity of water and cyclic nature were two complementary concepts to understand how children visualize the movement of water on Earth. According to Bar (1989) phase changes, free fall, and conservation of mass are the key background knowledge for children to explain water cycle. Similar with the Bar's findings, pupils in the study of Ben-Zvi-Assaraf and Orion (2005a) were aware of that the conservation of matter principle was applicable to the cyclic nature of the water. In contrast, Covitt et al. (2009) reported that the students in their study failed to integrate the law of conservation to natural water system. In our study, these two contrasting arguments mentioned above were found in our different cases. Eren and Ahmet were aware of that the amount of water on Earth is almost constant, whereas Cansu and Deniz had alternative conceptions. Among the participants, only Ahmet transferred his knowledge on the conservation of water to the cyclic nature of the water. Despite of explicitly stating, Eren failed to transfer his knowledge to the context of water pollution. He claimed that the amount of water in the water cycle decreases because of water pollution. During the interview phase 3, as he stated that he did not know the wastewater treatment techniques, he formed an *in-situ* answers that polluted water has a slower rate of evaporation and therefore, the amount of water in the water cycle would be affected. He presumed that unless water evaporates, it could not be considered within the water cycle. In short, he was not able to transfer his knowledge on conservation of matter to the cyclic nature of water. Similarly, Cansu claimed the amount of water is decreasing because they penetrated to the soil and not usable anymore. Based on our findings, we can conclude that even though a student is able to aware of the conservation of matter principle as a declarative knowledge, (s)he might not be able to use her/his knowledge to different contexts in the water system because they might not have adequate procedural knowledge to explain it. At this point, collecting multiple forms of data becomes crucial to discern this nuance. Even though Eren correctly responded in conception test and in the first phase of the interview, he could not be able to transfer his correct knowledge in another context. In the case of singular data collection tools, it might not be possible to acquire this information.



The second concept, cyclic nature, was studied by Ben-Zvi-Assaraf and her colleagues in their studies. For example, Ben-Zvi-Assaraf and Orion (2005a) reported that 62% of the participants held the misconception that water cycle has a beginning/ending point. In their another work, (Ben-Zvi Assaraf & Orion, 2005b), less than 10% of the students mentioned a cyclic component in their definitions even though they were able to identify different processes in water cycle. In our findings, all cases except Deniz declaratively stated water cycles repeatedly in the water cycle and no starting/ending point. Only Deniz consistently claimed that there is a starting/ending point of water cycle even though she mentioned how water 'cycle'. In terms of procedural knowledge, however, all cases in this study had difficulty to explain the correct mechanism of cycling nature of water. For instance, all cases except Deniz failed to explain evaporation on land surfaces and explained cyclic nature based on the evaporation from a water resource. Cansu claimed that the total amount of water is decreasing in the water cycle day by day, whereas Eren argued that polluted water decreases the amount of water in the water cycle. Overall, it can be deduced that even though students use the word 'cycle', they might have still lack of knowledge on its mechanism in water system context.

The third category 'properties of water' was formerly studied in the literature. For example, Bar (1989) and Forbes et al. (2015) reported that in the case of not having a necessary knowledge for phase change, children tended to explain a phenomenon in which water appeared in liquid state. In a similar manner, the students in this study explained water system mainly referring the liquid state of water unless it was asked to explain solid and gaseous state of water. None of them stated that water is the only matter that three states of water may coexist in the same temperature. Additionally, the mechanism of evaporation as one of the physical properties of water were traced In Ahmet and Deniz's responses.

Water and living organisms were mentioned by all cases unlike some of the findings in the literature. For example, Shepardson et al. (2007) reported that including biospheric components to their watershed conceptions was not frequent. Ben-Zvi

Assaraf and Orion (2005b) shared their result that less than 10% of the pupils included living organisms in their conceptions. In our study, before starting the interview phases, their drawing tasks were completed. Except Deniz, three cases did not include biospheric component in their water cycle drawing. Then, we explicitly asked about living organisms during the interview phases. Their statements related to water and living organisms were mostly formed when we asked them explicitly during the interview. In terms of types of knowledge, whereas all cases had fully correct declarative knowledge statements on the water and living organisms, only Eren and Deniz had fully correct procedural knowledge statement. Based on our findings, we can conclude that students are able to talk about the of biospheric components in the water system even if they did not include them in their drawing. In the second drawing task, which was about their local water system, only Cansu has drawn biospheric components. The reason for not including them in their drawing could be the fact that they imitate what they see in visuals about water cycle in different sources. This claim was also reported in the literature. Shepardson et al. (2007) highlighted that their drawings did not reflect students' hometown's characteristics but duplication of visuals in their science textbooks and other resources. In our study, the reason for not including biospheric components to the local water system characteristics could be the same with the same reason that Shepardson and his colleagues reported.

Last, the category of relational responsiveness was not found in the accessible literature. This was emerged in all cases' responses except Deniz. Ahmet explained both living and non-living subsystems' reactions. Eren mentioned solely non-living reaction, whereas Cansu explained the living subsystem's reaction when a change occurs in the water system.

Power sources of the water cycle were reported in the study Forbes et al. (2015) in an implicit manner. They worked with 3<sup>rd</sup> grade pupils and found that students had declarative knowledge on the role of gravity and temperature in the water cycle. They failed to reveal their procedural knowledge on the power sources in the water cycle.

Within the context of our study, the cases had partially correct statements in terms of both declarative and procedural knowledge.

Components and processes in the water cycle were extensively examined in the previous studies (Ben-Zvi-Assaraf & Orion, 2005a; 2005b; Derman & Yara, 2017; Shepardson et al., 2007; Shepardson et al., 2009). In terms of readiness of the students, they argued that most of the students had difficulties in basic aspects of identification of the system components. According to the result of these studies, students failed to include groundwater, runoff, and living organisms and mainly focusing on atmospheric components of water cycle. In addition to these, Derman and Yara (2017) stated that the most-frequently-mentioned concepts were water, cloud, rain, and evaporation, whereas photosynthesis was one of the least-mentioned concepts in Turkish context. In our findings, none of the cases mentioned rock, aquifer, hail, and freshwater among the 31 components. On the other hand, 13 components namely plant, sun, water, animal, human, ocean, sea, river, glacier, soil, groundwater, cloud and rain were all stated by all cases. Among the cases, only three processes namely evaporation, precipitation and melting were reported by all cases, whereas five of the 17 processes evapotranspiration, infiltration, underground flow, frosting, and dissolution were not traced in their responses. These results were partly compatible with the findings in the literature. All four cases explained their notion of water cycle by emphasizing its atmospheric components similar with the previous findings in the literature (Ben-Zvi-Assaraf & Orion, 2005a; 2005b; Derman & Yara, 2017; Shepardson et al., 2007; Shepardson et al., 2009). Different from the previous studies, all cases mentioned groundwater but as declarative knowledge. They explicitly stated that they did not know how groundwater forms. What is more, Cansu claimed that we could not use groundwater and its water is not included in the water cycle.

Interaction among the Earth (Sub)systems was the last category of FSL. In the studies of Ben-Zvi-Assaraf and Orion (2010a; 2010b), they examined students' notions on the interactions between the Earth systems through multiple data collection tools both as pre-test and post-test. Their pre-test findings indicated that students were mostly

talking about the interactions between “hydrosphere and atmosphere”, whereas “hydrosphere and biosphere” and “human and geosphere” were least ones. In our study, all cases mentioned some of the characteristics of the interactions between “hydrosphere-atmosphere”, “hydrosphere-geosphere”, “hydrosphere-biosphere”, and “hydrosphere-anthroposphere” either in their drawing or during the interview. The reasons for emerging biosphere and anthroposphere are as following: (1) I asked implicit questions like “Is there any other system hidden in your drawing that interact with the water system?” and “Is there any other system that might have interactions with the water system?” or (2) I asked explicit questions on the interactions of biosphere and anthroposphere if the participants did not mention them. However, in the case of atmosphere and geosphere, they reflected their notion on the question occasionally. Nevertheless, when we delved into their responses, most of the fully correct responses were declarative knowledge. Procedural knowledge statements, however were mainly partially correct.

To conclude, our cases had more declarative knowledge than procedural ones in terms of functional systems literacy. When we explored their nature of incorrect statements, more *in-situ* answers were diagnosed than the alternative conceptions. Their interaction maps produced mainly similar patterns with the other analysis conducted in FSL. Even though previous findings in the literature had similar results, the contributions of the findings of this study in terms of FSL can be summarized in four aspects. First, previous studies (Bar, 1989; Ben-Zvi-Assarf & Orion, 2005b; Derman & Yaran, 2017) asked general questions to understand students’ conceptions on water cycle. Based on the responses, they listed the most and the least frequently mentioned components, processes, and interactions among the Earth systems. In addition to general questions, I also added some specific questions related to biosphere and anthroposphere since they were reported two of the subsystems that ignored most of the K-12 students. Based on the analysis, it was determined that students had some conceptions in their mind even if they are mostly declarative and based on their daily life experiences. Second, I classified students’ knowledge as declarative and

procedural. Previous studies in the literature already mentioned that K-12 students' conceptions of water were naïve and mostly declarative. I believe that adding this classification enabled us to gain deeper understanding about their notions. Third, making distinction between alternative conceptions and in-situ answers might have another contribution that the present study made. Understanding the nature of incorrect responses could guide the educators and curriculum developers about how to revise existing teaching materials to diagnose and minimize those alternative conceptions and in-situ answers. Last, individual interaction maps enabled us to see how the categories of FSL were interrelated in students' mental models. Moreover, these interaction maps also indicated limited understanding of FSL of the students by producing weak interactions.

### **6.2.2 Cultural Systems Literacy**

The findings of within-case analyses revealed three categories in CUSL as (1) components of local water system; (2) national water resources; and (3) relationship among the local, national, and global (sub)systems. Further, the first category divaricated into subcategories as local water resources, water supply network and sewerage system. Cases' responses in these three categories were classified the same as done in FSL part. Moreover, enumerative approach revealed the patterns of the interactions among the categories of CUSL. Cross-case findings, on the other hand, showed similarities and differences among the cases. To be reader friendly, I firstly discussed the issues of declarative/procedural knowledge and alternative conceptions/in-situ answers through providing the previous findings in the literature. Then, I provided a discussion for each category and interaction maps as well.

The findings of this study revealed that even though Cansu and Ahmet performed better than their peers at some points, all cases had limited amount of knowledge on the basics of their local water system. In terms of types of knowledge, all four had more correct declarative knowledge than procedural ones as in their FSL. What is more, Eren and Deniz had no fully correct procedural knowledge statements on the

basics of their local water system. This is not surprising because there are similar results reported in the literature (Ben-Zvi Assaraf, Eshach, Orion, & Alamour, 2012; Covitt et al., 2009; Shepardson et al., 2007). They all reported that the idea that majority of children do not associate water cycle and their residence areas; have naïve conceptions; have lack of understanding about the basics of their local water system.

As stated in the former section, Mills (1983) had a study to assess students' achievement on water included both social and natural science concepts and reported that students living an urban area had relatively higher scores than rural students. By contrast, Shepardson et al. (2007) claimed that rural students could have more sophisticated conception on the water cycle than their urban peers. Taiwo et al. (1999), on the other hand, reported that rural students in Botswana had statistically significant greater performance in their understanding of the water cycle in terms of socio-cultural elements but the analysis of the interviews reflected that their understanding of the water cycle was not clear in their minds. In our study, Cansu was living a rural area, while Ahmet was an urban student living in a seaside, but he also has a house in a village. In terms of CUSL, Cansu and Ahmet performed better than her peers while they were explaining the basics of their local system. However, even though Eren was one of the top-ranking students in Turkey in the national entrance exam and performed better compared to other cases in FSL tasks, his notion of CUSL was very limited and full of in-situ responses. Thus, within the context of our findings in terms of CUSL, it would be hard to say that either urban students had relatively higher scores than their rural peers or rural students have more sophisticated conceptions than their urban peers in water context. Having more interactions with his/her local water system could enhance the performance of the students in terms of socio-cultural elements as Taiwo et al. (1999) emphasized.

In terms of alternative conceptions and in-situ answers, cases in this study produced mostly in-situ answers that are inconsistent and varied from different context to another. Their in-situ answers were compatible with the findings of Covitt and her colleagues (2009), even though they did not name these statements as “in-situ”

answers. They found that students failed to see the interaction of water supply network with the other systems and they were not be able to differentiate different water treatment plants. In the present study, all cases failed to see the interrelationships between water supply network and the other systems on Earth. Except Ahmet, they did know the differences between different water treatment plants. Even though Cansu and Ahmet articulated drinking water treatment plant, they did not know how this plant work in detail. Except Ahmet, no other cases had an idea about wastewater treatment plant. Thus, they produced in-situ answers to the question “where does water go after we use it in our homes?”

In their two drawing tasks, cases were asked to draw a water cycle and their local water system. Shepardson et al. (2007) conducted a study related to watershed and they reported that man-made storages were more visible among the urban students because they saw them in their daily life, whereas rural students drew natural storages of water more since they have possibility to see ‘farm ponds’ in their agricultural fields. Although our cases did not pronounce the term ‘watershed’, they produced similar icons in their drawing. Eren added some man-made storages in his first and second drawing task; Deniz and Ahmet added man-made storages in their second drawing task; Cansu added both natural and man-made storages in her second drawing task. In addition to these, Shepardson and his coworkers emphasized that students imitated the visuals available in the textbooks and the other resources and did not associate the watershed with their residence areas. In a similar manner, all drawings related to the first drawing task imitated the visuals given in national science textbook. Their second drawings were not associated with their residence areas except Cansu and Ahmet even though their drawing had minor drawbacks. They also did not include the concept of watershed neither in their drawing nor to their responses during the interview. Yazıcı and Samancı (2003) investigated 5<sup>th</sup> grade students’ understandings in a Turkish context and their findings indicated that most of the pupils provided no answer related to watershed concept. In this study, the cases did not use the term watershed. The reason for this limitation could be attributed to the middle school curriculum since

watershed is not a concept given in the middle school courses. Hence, students might not have a proper understanding of their local water system since they did not meet the term ‘watershed’.

Students’ conceptions on the components of local water systems were traced through second drawing task and interview. All cases identified the components of local water system as animals, plants, human beings, local water resources, water supply network, and sewerage system. Additionally, Eren mentioned that microorganisms were also one of the components of his local water system. Despite of identifying all the components, all cases provided limited amount of information about the functions and role of these components in their local water system.

The category of local water resources was one of the subcategories that cases had difficulty to reveal their declarative and procedural knowledge. Except Cansu, the other three cases did not know which freshwater resource(s) provide drinking water to their home. Instead, they provided in-situ answers. While Eren stated that they used groundwater in their local water system, Deniz and Ahmet claimed that rainwater accumulated the dams and these dams provided drinking water to their homes. Cansu and Eren, on the other hand, did not mention about the dams as an entity. Based on the findings, it can be inferred that cases were not aware of how dams are built and how they store water, even though rainwater and groundwater could be theoretically one of the water resources of dams. What is more, they did not know the name of freshwater resources in their hometown except Cansu. She stated that River Kızılırmak is located near their village and she had multiple interactions with that river. Moreover, she reported that she had heard about further information from their mayor. The other cases in this study had no specific daily life experience with their freshwater resource(s). Thus, it can be concluded that daily life observation and secondary resources could help Cansu to visualize her local water system in her mind. This conclusion can be supported with further evidences. Eren, Ahmet, and Deniz named the other local water resources that are used for recreational and other purposes. Eren and Deniz who live in the same city knew the name of the lakes that people go around for recreational



purposes. They also stated these lakes are used for survival purposes for the organisms living around the lakes. In the same manner, Ahmet mentioned the sea that is located in his hometown and stated its function as recreational, economical and industrial purposes. The functions of local water resources were also partly studied by Havu-Nuutinen, Kärkkäinen, and Keinonen (2011). Their reports that fourth and fifth graders attributed the role of water to human beings by means of domestic and recreational purposes even though these notions were limited. Within the context of the study, these purposes were also mentioned by the cases. Eren and Deniz had limited understanding on the functions of LWR based on their daily life experiences. Cansu and Ahmet provided further information about the functions of their local water resources based on their observations, interactions as well as information from secondary sources. Thus, our findings were partly compatible with the study of Havu-Nuutinen, Kärkkäinen, and Keinonen (2011).

In terms of water supply network and sewerage systems, all of the cases in this study stated that they did not know the entire mechanism of water supply network and sewerage system. Covitt et. al (2009) reported that majority of the students stated that water in their taps is coming from a natural source and we had similar findings in our study. They also reported that majority of the students presumed that both drinking water and wastewater should be treated; however, a few of them indicated the treatment plants. In our study, Cansu and Ahmet were aware of the drinking water treatment plant as an entity. In terms of sewerage system, Covitt et. al (2009) found that one fourth of middle school and nearly half of the high school students reflected that water is also retreated somewhere like a treatment plant after they use it at home. In our study, however, only Ahmet stated that there could be a wastewater treatment plant. As a candidate of “in-situ” answer, the high school students in the sample of Covitt and her colleagues (2009) claimed that treated wastewater is ‘recycled back’ to the households and they failed to indicate discharging to a receiving environment. In our study, Ahmet had similar “in-situ” answers.

Even though we did not intend to elaborate, some of the cases talked about national water resources more than the other cases. The only question related to national water resources was about the status of water-richness of our country. Nevertheless, Deniz was talking about national water resources more than her local water system. She gave more examples from Turkey in her responses and mentioned the status of pollution as a macroscopic and failed to mention microscopic level of pollution in the water resources that she visited and heard from the media. Her notion related to pollution was compatible with previous studies (e.g. Covitt et al., 2009; Endreny, 2010; Österlind & Haldén, 2007). Ahmet, on the other hand, mentioned both his local and national water system. Eren responded only the question about the status of water-richness of Turkey during the interview. Unlike them, Cansu did not talk about national water resources, but she mentioned mostly the local water system in her hometown compared to her peers. All cases shared their first-hand experiences as well as information that they gained through media while they were expressing their notion. Thus, these two sources might shape their mental models on their local/national water system.

In terms of relationship among the local, national, and global (sub)systems, all cases had more fully correct statements compared to other categories. Nevertheless, they had also alternative conceptions and in-situ answers. All cases were able to see the relationships “LWS- Hydrosphere”, “LWS-Biosphere”, “LWS-Anthroposphere”. All cases except Cansu would not be able to relate local water system and water supply network. Similarly, Covitt et al. (2009) reported that pupils had informal reasoning about water systems and their notions are limited to underground pipes and they fail to see the interaction of water supply network with the other systems. In our study, we saw the similar patterns among the cases. They were not be able to identify interactions among their water supply network, sewerage systems and the other systems. Cansu was the only participant that would be able to relate her local water system and water supply network even though she partly explained the nature of the relationship. In terms of interactions of LWS to biosphere, hydrosphere, geosphere, and

anthroposphere, she shared solely her first-hand experiences. This is not a surprising finding too because she had limited amount of knowledge in terms of FSL. Therefore, mentioning first-hand experiences for the interactions between local and global system is an expected finding. On the other hand, Eren was not be able to transfer his notion of cyclic nature in FSL to his local water system. The other relationships that he referred seemed to be more theoretical rather than based on his first-hand experiences. He explained the relationships among LWS, biosphere, anthroposphere, and geosphere in terms of dissolved oxygen, evaporation, photosynthesis, microorganisms, and aesthetic views of the lakes which were indicators of theoretical knowledge rather than experiences. This is not a surprising finding too because he had limited amount of knowledge in terms of CUSL. Therefore, selecting theoretical knowledge as baseline to explain the interactions between water and the other systems is an expected finding. Unlike Eren, Ahmet was able to transfer his understanding on the cyclic nature to his local water system. The other relationships, on the other hand, were mentioned by him in a superficial manner. He shared his first-hand experiences in his hometown to explain interactions between the local and global systems. Among the cases, Deniz had difficulties to express the interactions among the local, national, and global (sub)systems. She mainly mentioned the interactions among the national and global systems. This was also an expected finding because Deniz had difficulties in both revealing her FSL and CUSL. In previous studies, some of similar findings were reported. For example, Ben-Zvi Assaraf et al. (2012) indicated that more participants from Bedouin community included items related to the geosphere such as penetration, groundwater, and surface flow and included interactions between the Earth systems and geosphere. In a similar manner, Cansu who was a rural student in this study included similar items in her drawing compared to her peers. Besides Cansu, Eren and Ahmet also included geosphere either in their drawing or in their responses during the interview. Nevertheless, they had alternative conceptions and in-situ answers on this interaction. Additionally, Ben-Zvi Assaraf et al. (2012) denoted that Bedouin students included human aspect more than their urban peers in general. In the case of Cansu, she also mentioned the interactions on LWS-Anthroposphere more than others. Last,

individual interaction maps enabled us to see how the categories of CUSL were interrelated in students' mental models. Moreover, these interaction maps also indicated limited understanding of CUSL of the students by producing weak interactions or no interaction.

### **6.2.3 Critical Systems Literacy**

The findings of within-case analyses revealed two themes in CRSL as (1) Advance mechanisms of water system; and (2) Invisible elements of human system. Further, these two themes divaricated into categories. Cross-case findings presented similarities and differences among the cases. In this section, I provided a discussion for each category.

#### *Advance Mechanisms of the Water System*

Advance mechanisms of water system were categorized as (1) dynamic nature; (2) causalities and feedback loops; (3) evolutionary processes; and (4) complexity of the water system. Dynamic nature was addressed in the previous studies (e.g. Ben-Zvi-Assaraf & Orion, 2005a, Feriver-Gezer, 2018). For example, Ben-Zvi-Assaraf and Orion (2005a) put dynamic relationships within the system as one of the characteristics of systems thinking. They examined the dynamic nature of the water cycle within the context of the groundwater movements as well as phase changes of the water. Besides, they examined time dimension, thinking temporally, as another system thinking skills. On the other hand, Feriver (2018) addressed dynamic thinking as one of the systems thinking skills of young children. She operationally defined dynamic thinking as ability to being aware of the dynamic changes in a system related to both visible and hidden components and processes within that system. Within the context of the study, I preferred to use the description of Mobus and Kalton (2015) for dynamic nature since their description was not only included the definitions of previous studies that I summarized above but also more comprehensive and compatible with the notion of systems science.

At the beginning of the study, I presumed that the term ‘dynamic’ could be unfamiliar to the 9<sup>th</sup> graders. Thus, I preferred to use a context in the water system where students could be able to talk about dynamic nature of the water system without using any unfamiliar term. I chose the context of unconscious use of water as a change in the system and I asked indirectly its dynamic effects on that water system. All four cases were aware of the possible reasons for time delays in the water system, however they failed to elaborate their dynamic effects of time delays in water system. For instance, while Deniz and Ahmet attributed time delays to overpopulation, Eren and Ahmet mentioned the effects of water pollution on the time delays in the water system. These issues were also reported in the study of DeLorme, Hagen, and Stout (2003). Adults’ list of the possible reasons for experiencing water issues included drought and population growth, and residents’ misuse of water. In terms of redistribution of the water, Eren and Ahmet emphasized the role of global warming and climate change on redistribution of water. On the other hand, Cansu and Deniz had statements that were indicators of lack of dynamic conceptions. While Cansu mentioned that groundwater resources remained below the surface and cannot be used, Deniz stated that water precipitates where it evaporates. These statements were indicators that they failed to consider groundwater, precipitation and evaporation as dynamic concepts, but rather static. Additionally, all participants had some in-situ answers that they could not able to transfer them into other context and alternative conceptions as well. Since Cansu and Deniz did not know that the total volume of water is almost constant on Earth, they tried to explain dynamical mismatches based on this alternative conception. These findings were also present in some studies. For example, Ben-Zvi-Assaraf and Orion (2005a) reported that students had lack of understanding on dynamic relationships within the system before intervention and some of them did not be able to improve their skills after the learning process. Moreover, they denoted that thinking temporally was one of the most difficult STS among the others to achieve. Feriver-Gezer (2018) similarly addressed that young children tended to identify changes in a system where gradual change was observed. However, they were not being able to perceive ‘circular dynamic behavior pattern’. Within the context of our study, even though they were

able to detect time delays in the water system, they failed to explain the processes in detail. Moreover, their alternative conceptions distorted their understanding of dynamic nature of the water system. Even though Covitt et al. (2009) did not explicitly use the term ‘dynamic nature’, some of their results indicated dynamic nature of the water system. They reported that students in all grade levels were able to aware the human effects on the quality of water as well as its circulation in systems. Majority of the students explain the water flow based on their observations, yet they failed to follow the water and materials within between observable and hidden parts of system. These results were also observed in our cases’ responses.

Causalities and feedback loops was another category of the advance mechanisms of the water system. In educational context, previous studies included causalities and feedback loops in several combinations. Ben-Zvi-Assaraf (2005a) and Karaarslan (2016) included no feedback loops in systems thinking skills, while they traced causality in some of the specific characteristics of system thinking. Feriver-Gezer (2018) examined them as two different characteristics which are namely one-way causality and feedback thinking. Sweeney (2001) defined feedback loops similar with Mobus and Kalton’s notion as ‘circular cause-effect relationships’. Within the context of the study, I prefer to use Mobus and Kalton’s description. Findings of this study revealed that all four cases mentioned a simple reinforcing loop in an implicit manner. Except Cansu, all three cases revealed at least an open loop with multiple causalities. Among the cases, only Ahmet’s responses indicated balancing loops. According to Mobus and Kalton (2015) these simple loops and open loops are rare in real world and thus do not reflect the actual situations. In our study, none of the cases revealed multiple closed-loop systems except Ahmet. To conclude, their causalities and feedback loops of the cases were simple and are very rare in the real-world settings.

Evolutionary process of the systems was adopted the principles listed by Mobus and Kalton (2015). According to their definition, systems have three evolutionary tendencies as decaying, stead-state, and towards a higher organization. None of the cases in this study mentioned about towards a higher organization. The tendency of

the cases was about decaying state of the water system for local, national, and global level. This finding was compatible with PISA 2015 results of Turkey (OECD, 2017). Among the questions of scientific literacy, possible future scenarios of environmental issues over next 20 years were asked to Turkish students. Water shortage and increase of greenhouse gases in the atmosphere were the items related to the scope of this study. Turkish students' responses were pessimistic about them. More than two thirds of them stated that these issues will get worse (65.3% for water shortages, 64.7% for greenhouse gases emissions). The percentages of the students for claiming steady state were 14.8% for water shortages, 17.3% for emissions of greenhouse gases. In our findings, three cases talked about decaying of the water system, while two of them expressed the conditions for staying steady state.

As in the dynamic nature of the water system, I preferred to use a context in the water system where students could be able to talk about complexity of the water system without using any unfamiliar term. I selected the issue of climate change and hidden use of water as two of the interruptions in the water system and possess many layers of complexity such as economic, social, environmental, educational, health, and governmental layers. The comparison of cases' responses revealed that all four cases were able to detect interruptions as global warming and climate change, while only Eren and Ahmet provided fully correct procedural knowledge on the mechanisms of global warming and climate change. Additionally, Ahmet revealed some misconceptions related to global warming and ozone layer depletion. In terms of layers of complexities, all cases reported environmental and social layers of complexities. Ahmet and Deniz mentioned also economic and health layers, while Eren was talking about economic effects. To conclude, they were able to detect climate change as an interruption and those who have more enriched FSL than their peers revealed correct procedural knowledge on global warming and climate change. However, they need to have in-depth information about layers of complexities in the water system.

Hidden use of water was another context for complexities in the water system which is being hardly studied in K-12 literature. Moreover, the term 'hidden' was used by

the researchers in water education context in different meanings. For example, Ben-Zvi-Assaraf (2005a) referred the concept of underground water, while Covitt et al. (2009) encountered aquifers, water vapor, water in treatment systems as ‘invisible’ parts of water system. What is more, Covitt and her colleagues reflected that macro components such as watersheds are also invisible to the students. Venckute et al. (2017) and Benninghaus et al. (2018) used the term ‘hidden use of water’ or ‘virtual use of water’ as water consumption while producing a product. Within the context of the study, I preferred to use their description. The findings revealed that Eren and Deniz have never heard about the term “hidden use of water”, whereas Ahmet and Cansu reported that they learned the term from extracurricular activities. Even though Eren and Deniz were not familiar with the term, they were able to infer some processes in which water is spent for a product, in our case, hamburger. Nevertheless, they failed to indicate all processes that spent during production. Cansu and Ahmet, on the other hand, were aware of that too much water is spent to produce a hamburger compared to daily direct use of water. All the cases except Deniz reported that consumers were responsible for the water consumption to produce a hamburger. Deniz argued that the people serving in the production phases were responsible for the water consumption.

If there is no intervention, some studies reported that young people could not be able to aware of the hidden components in a system (Ben-Zvi-Assaraf & Orion, 2005a; Benninghaus et al., 2018; Covitt et al., 2009; Forbes et al., 2015). Our findings were compatible with these studies. Venckute et al. (2017) studied to make an approximation for water footprint of pupils and they illuminated that pupils’ hidden use of water is much higher than the direct use of water. Among the hidden use of water, food (84.4%) and clothing (6.4%) were the first two elements. At this point, I believed that it is crucial to teach pupils about the concepts of hidden use of water as well as water footprint to enhance their systems literacy in water context. In our findings, even though an individual is familiar with the term, (s)he could not be able to aware all processes during the production and correspondingly, his/her water footprint. Therefore, in my professional opinion, formal education could provide a



baseline to the participants on this context. Additionally, Deniz stated that she was not responsible for water consumption of a hamburger. In a similar manner, I believed that teaching students the concept of water footprint could help change such preconceptions.

To conclude, critical systems literacy of all the cases in this study was limited in terms of advance mechanisms of the water system. While their CRSL were interacted with their FSL and CUSL, it also obscured by their alternative conceptions and in-situ answers.

### *Invisible Elements of Human System*

Invisible elements of human system as a second theme in CRSL involves the categories of beliefs about water use, action strategies for efficient/sustainable water use, self-efficacy beliefs towards efficient/sustainable water use, emotional responses, motive concerns, and motivational orientation for efficient/sustainable water use. The findings of the study reflected that this theme could have multiple interactions and interlinkages with individuals' FSL and CUSL as well as the advance mechanisms of the water system. In this part, each category was discussed, and their possible relationships were summarized.

The literature on beliefs is too broad that makes it impossible to include them in this study. Thus, I specifically chose to focus on beliefs on water consumption behaviors to be more compatible with my operational definition for systems literacy. Deniz did not know the term hidden use of water but believed that she used water efficiently more than the other people. In contrast, Eren also did not know the same term but he was more cautious than Deniz hoping that he was not wasting water too much. The sources of their beliefs were based on daily life experiences with direct use of water as well as inferences made from his/her observations. Ahmet, on the other hand, was aware of hidden use of water, yet he believed that he did not consume water too much compared to adults' consumption patterns. Among them, Cansu seemed to have beliefs compatible with her water consumption behaviors, although this assertion needs to be

verified by her water footprint data. She explained her sources of her beliefs with her daily life experiences as well as her knowledge on water consumption. At this point, I agree with the idea that beliefs are essential constructs to be determined because beliefs have potential to interfere with learning practices (Keys & Bryan, 2001) as well as behavior (Corraliza & Berenguer, 2000) which could provide also baseline for critical systems literacy. In this study, Deniz and Eren believed that their water consumption behavior is efficient, but their responses was limited to saving tap water. This type of belief was also apparent in the study of Wood (2014) and DeLorme, Hagen, and Stout (2003). However, an individual who does not have enough background knowledge might develop a belief on his/her behavior which could not be compatible with the actual situation. In water system context, if a person is not aware of his/her hidden use of water, (s)he might develop a belief that (s)he is an efficient user which may not reflect his/her actual water footprint. What is more, even if that person is willing to reduce his/her water use, incompatible beliefs might hinder him/her to modify his/her water consumption behavior.

Action strategies for efficient/sustainable use of water was another category in CRSL. The reason I included the term sustainability is that systems literacy in water context has potential to be include sustainable development goals since these goals have multiple interactions with systems literacy. At the beginning of the study, I presumed that students could be able to talk about sustainability and transfer their knowledge on sustainable water use since they were supposed to learn the concept of sustainability from their middle school curricula. However, only Eren had substantial amount of knowledge on sustainability, whereas the other three cases did not know about it. Thus, I preferred to talk with them about action strategies 'efficient use of water' and asked the reason(s) for efficient use of water. Except Ahmet, three cases reported some action strategies related to their direct use of water. Among them, only Cansu mentioned action strategies for monitoring her hidden use of water. Ahmet reported no specific action strategies related to his water consumption behavior neither direct nor hidden use. In terms of direct use of water, Cansu and Deniz provided detailed information on

how to reduce their water consumption in their daily life. Eren did not prefer to explain them in detail but summarized his water efficiency behaviors as doing the ‘cliché’. Some of our findings were compatible with the previous findings reported in the literature. For example, Wood (2014) conducted a study on water literacy within the context of ESD in UK and found that younger students’ perceptions on saving water was limited to ‘water saving tips’ which were commonly included in the water contexts in schools. The most frequently mentioned water saving was turning off the taps during brushing their teeth. In a similar manner, our cases in this study reported the same ‘water saving tips’. Additionally, Wood (2014) listed the sources of these tips as TV/radio, school, internet, family, newspapers/magazines, and post/leaflets. In this study, cases reported their sources as school, internet, and family. Different from the findings of Wood, Eren and Cansu also exemplified the role of persuasion of other people to invite them use water efficiently as an action strategy for efficient water use. In terms of sustainable water consumption strategies, Eren shared his theoretical knowledge on action strategies included future generations, energy-efficiency, and preventing water pollution which are related to some of the sustainable development goals. Nevertheless, he listed them based on his hypothetical project, not a reflection of his actual water consumption behavior. Hence, based on his data, it is not possible to make inference about integration of his knowledge on sustainability into his action strategies. Further data are needed to explore the nature of this interaction in our national context.

Self-efficacy beliefs toward efficient/sustainable water use were not emerged in all cases of this study. Female participants, Cansu and Deniz, showed some indicators that can be considered as high self-efficacy. Both stated that they use water efficiently most of the time and they know how to water use efficiently. However, Ahmet and Eren did not have specific statements that could be indicators of high/low self-efficacy. There could be possible reasons for this difference. First, females might tend to exhibit their high self-efficacy beliefs than their male peers. This proposition was tested in some studies which might be related to water system context. For example, Meinhold and

Malkus (2005) reported self-efficacy was a moderator variable for females. They reported the correlation between environmental attitudes and behaviors were statistically significant in favor of high self-efficacious females. However, this was not the case among male participants. Based on the results, the researchers articulated that self-efficacy beliefs could be considered as moderator variable for females, whereas it could be an independent variable for males. Nevertheless, they recommended further studies for this proposition. In the same manner, the findings of this present study might be compatible with Meinhold and Malkus's results. Deniz and Cansu provided detailed information on how they consume water efficiently in their daily life. Based on their self-reported water consumption behavior and high self-efficacy beliefs, one can deduce that these two constructs might have same correlation pattern with certain studies previously reported in the literature. However, as Meinhold and Malkus denoted, further investigations are still needed to understand the interaction of these constructs. Second, self-efficacy beliefs of male participants in this study might not be developed yet due to several reasons. For instance, Eren's self-efficacy beliefs might not be emerged because of the very nature of the definition of self-efficacy. Self-efficacy was defined by Bandura (1986) as following: "People's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances" (p.391). As discussed in the previous sections, even though Eren had more sophisticated FSL compared to his peers, his procedural knowledge was weak, and he also had limited amount of knowledge about his local water system. What is more, he did not know the meaning of hidden use of water and therefore he might not be able to aware of his water consumption pattern. All these limitations might hinder his critical systems literacy. Hence, his self-efficacy beliefs toward efficient use of water might not develop yet since he could not be able to judge his capabilities to implement and monitor his actions in water consumption context. In this scenario, it will not be a surprising finding. Ahmet, on the other hand, had similar FSL with Eren. Furthermore, he had also considerable amount of knowledge on his local water system as well as the meaning hidden water use compared to Eren. Despite of these differences, no self-efficacy beliefs was detected in Ahmet's responses. He

reported that his direct and hidden use of water were not too high compared to adults, so no further action was needed to monitor it. His beliefs on personal use and collective use of water might impede him from developing self-efficacy beliefs toward efficient water use. Venckute et al. (2017) made an approximation for water footprint of pupils and the result illuminated that their hidden use of water is much higher than the direct use of water. Based on the data they acquired, the researchers concluded that pupils spent too much water and this needs to be regulated through the educational activities. At this point, I agree with the study of Venckute et al. (2017) in a way that if do not promote individuals' learning on their actual water consumption behavior, one might not be able to monitor accurately his/her water consumption behavior. Accordingly, they might suppose that they already use water efficiently and this belief might be developed based on their misperception on their water footprint.

Every case in this study revealed unique combinations of emotional responses related to their self-water use and other people's water consumption behavior. Eren explained his feelings hypothetically whereas Cansu and Deniz shared their sadness whenever they witnessed an inefficient use of water. On the other hand, Ahmet reflected his apathy to regulating and monitoring his water consumption behavior. Eren's hypothetical explanation was not, again, surprising because he generally tended to construct hypothetical propositions rather than sharing his own experience. Female participants' emotional responses were also expected findings since they share their action strategies as well as motive concerns related to the presence of water. Last, Ahmet' apathy was also not surprising because he shared neither any action strategies nor motivational orientation towards efficient water use. In addition to these, these findings were also apparent in the previous studies as females tend to be more upset than their male peers (Arcury & Christianson, 1993; Gambro & Switzky, 1999; Gifford & Nilsson, 2014; Levine & Strube, 2012).

### *Motive Concerns and Motivational Orientation*

All cases reflected the two motive concerns as social altruistic and biospheric. However, the dominant one in responses was social altruistic except Deniz's responses. Deniz had no dominant motive concern and she mentioned the importance of water for both living organisms and human beings. Stern, Dietz, and Kalof (1993) denoted that individuals could have more than one motive concerns for a context. Within the context of the study, all cases had multiple motive concerns which was compatible with the claim of Stern et al. (1995). In terms of motivational orientation, all cases except Ahmet revealed extrinsic motivational orientation towards efficient water use. Doing the right things, importance of performing behavior for the lives of people and living organisms were the reasons that they provided a rationale to their motivational orientation. Some researchers (e.g., Khachatryan et al., 2013, Thøgersen, 2011) reported that altruism could be one of the indicators for pro-environmental behavior. In a similar manner, the responses of this study revealed that social altruistic motive concerns of the cases motivated them to use water efficiently. Nonetheless, as Corral-Verdugo and his colleagues (2002) forewarned, social desirability could be correlated with the responses related to motivation towards efficient water use. Thus, more comprehensive studies are needed.

Ahmet, unlike from his peers, had amotivation and did not have specific goal for using water efficiently. Among the three types of amotivation, Ahmet's amotivation was classified as lack of competence because one believes that individual actions are not effective itself (Ryan & Deci, 2017). In a similar manner, if he was a person that uses water recklessly, then he would regulate his water use provided that everybody else changed their water consumption behavior. Wood (2014) reported that older students articulated feelings of helplessness towards wide-ranging water issues. In a similar vein, Ahmet's amotivation could be related to that context.

Interaction map (see [Figure 5.42](#)) revealed some interactions among the elements of human system. Cases mainly determined their action strategies based on their direct

use of water, motivational orientation, and motive concerns. Then, their beliefs on their water consumption behavior and self-efficacy beliefs contributed to monitor their action strategies and this monitoring promote their beliefs and self-efficacy beliefs. These types of sub-cycles were emerged from their responses and all these interrelations were provided in the interaction map. Of course, these interactions do not have to be factual statements and not suitable for generalizing. However, in-depth interview and multiple data collection tools could provide to unveil these interactions. This interaction map should be tested and verified by quantitative further studies.

To conclude, based on the previous studies and the findings of the present study, a critically systems literature individuals who completed his/her middle school degree could be defined as the one that would be able to (1) have accurate declarative and procedural knowledge on the advance mechanisms of water system; (2) have less alternative conceptions on the system; (3) grasp systems in its dynamic nature on multiple time scale and be aware of potential effects of different time scales on system dynamics; (4) explain different types and levels of complexity in a system which can be the basis for disruption or failure within a system; (5) describe evolutionary processes of systems; (6) draw or explain feedback loops which are for regulating subsystems to provide maintenance; and (8) predict that different mental models of humans may interfere with the interaction between man and nature; and (9) appreciate that systems can be understood and improved. What is more, the elements of beliefs, action strategies, self-efficacy beliefs, motive concerns, emotional response, and motivational orientation for maintaining a system were also potential constructs to indicate individuals' critical systems literacy. At this point, in order to promote critical systems literacy, nurturing both FSL and CUSL is essential. Moreover, to motivate them for maintaining a system, determining individuals' beliefs, action strategies, motive concerns, self-efficacy beliefs, and emotional response could also be as important as FSL and CUSL.

Stables (1998) argued that critical literacy demands both functional and cultural literacy. In other words, critically systems literate students are expected to have

adequate level of functional and cultural systems literacy. The overall findings of this study provided some potential evidences to support Stables's argument. Critical systems literacy of all four cases seemed to be inhibited by inadequate functional or cultural systems literacy. Even though Ahmet could be regarded as adequate level on both functional and cultural systems literacy, his amotivation and apathy seemed to make his critical systems literacy limited especially within the context of invisible elements of human system. At this point, both adequate level of cultural and functional literacy and motivational orientation could be the key points to cultivate critical systems literacy. In the next section, possible factors interfering with systems literacy in water context were discussed.

### **6.3 Possible Factors Interacted with Systems Literacy in Water Context**

As Sweeney (2012) claimed, individuals could have 'innate ability' to be a system-literate. In a similar manner, I believed that individuals could have innate ability to see systems behavior without having formal training to learn how to do it. In addition to these, I am also aware of that their perceptions related to systems behavior could be distorted and also shaped by many factors some of which I hope to detect in my study. In this study, several information was asked to each case to portray their profile as well as to determine possible factors that might interact with their systems literacy in water context. Their gender, percentile of their national exam score, types of high school, location of the house, parent's occupation, and participation to extracurricular activities were the variables that I collected additional data to search for possible factors interacted with systems literacy. I presented a discussion comparing the literature's findings and my analysis.

In terms of gender, several differences existed among the cases even though these differences require further verifications. When FSL of the cases were compared in terms of gender, boys seemed to have richer understanding on the basics of the water system. In terms of CUSL, however, no specific differences were detected between genders. On the other hand, the situation within the context of critical systems literacy



was different. At the beginning of the study, I expected that individuals who had richer understanding in FSL could have better CRSL in this context. However, findings of the two themes were different from each other. The first theme of CRSL was about the advance mechanisms of water system and boys had richer understanding compared to girls even if their understanding was limited. On the other hand, the findings of the second theme was quite opposite compared with the first one. Even though girls had limited amount of knowledge in FSL and Deniz further had limited amount of CUSL, girls seemed to be more motivated than boys for using water efficiently; have more detailed action strategies accompanied with high self-efficacy beliefs. Moreover, they seemed to be more concerned about the water system and have more intensive emotional responses than boys. Gender differences was widely studied in educational literature. Even though the context of water use was not one of them, the studies on pro-environmental behavior had some converging points with the findings of the present study. To be reader friendly, I reported here only the review of Gifford and Nilsson (2014) related to the possible factors that interacted with pro-environmental behavior. They reported that even though studies in 80s are inconclusive about the gender differences, recent studies in 14 countries concluded that females revealed more positive attitudes, more concerned than their male peers. Additionally, males have richer knowledge than females in environmental subjects. The reasons for gender difference were beyond the scope of this study so I will not go into the details. The point here is that the girls revealed the same patterns as reported in pro-environmental behavior studies. They tended to use water more efficiently than their male peers.

In the literature, level of achievement or cognitive differences (e.g. Ben-Zvi-Assaraf & Orion, 2005a) were claimed to be a factor that interact students' conceptions on water. Ben-Zvi-Assaraf and Orion (2005a) reported that individual cognitive differences is one of the variables that were interacted with the pupils' individual progress. In our study, FSL covered natural science concepts, while CUSL and CRSL included both natural science and social science concepts. When we compare our findings in FSL, no clear distinction was observed in our cases. Both conception test

and comparative analysis formed a similar pattern with their national exam scores or their level of achievement. From this perspective, it is seen that their FSL and level of achievement could be directly proportional to each other. However, when we delve into the responses in terms of declarative/procedural knowledge and alternative conceptions, the lines are blurred. All participants had more declarative knowledge than their procedural knowledge. Among the participants, Cansu had the ones that had least fully correct declarative knowledge statements than others. In terms of procedural knowledge, Cansu had no fully correct statements. Nonetheless, Deniz had the ones that had more incorrect statements and alternative conceptions than others. In CUSL, the situation was different. In this element of SL, Cansu and Ahmet had more fully correct statements than Deniz and Eren. Among the participants, Deniz had the ones that had least fully correct declarative knowledge statements than others. In terms of procedural knowledge, Eren and Deniz had no fully correct statements. In a similar manner, they were the ones that had more incorrect statements and in-situ answers than others. In short, the premise of “cognitive difference could be a factor that interact students’ conceptions on water” was verified only for declarative knowledge in FSL in this study. If the findings are assessed as a whole, it would be hard to say that level of achievement and cases’ systems literacy are positively correlated with each other. Still, in the work of Ben-Zvi-Assaraf and Orion (2005a), cognitive difference is a variable that has a role in students’ progress in systems thinking. Hence, further studies are needed to see the role of cognitive differences in individual’s progress by means of systems literacy.

Mills (1983) administered a test included both social and natural science concepts and reported that students living an urban area had relatively higher scores than rural students. In contrast, Shepardson et al. (2007) contended that rural students could have more sophisticated conception on the water cycle than their urban peers. In our study, these contrasting findings behaved differently in students’ FSL and CUSL. In conception test, Cansu, who lives in a rural area, did not bring up the rear. However, she had lower scores than her peers in comparative analysis as well as in procedural

knowledge in FSL. Nonetheless, the winds have changed in terms of CUSL. She performed better than her urban peers while she was explaining the basics of her local system. Thus, if these findings were considered as a whole, it would be hard to say that urban students had relatively higher scores than their rural peers. Rather than living in urban or rural area, I presumed that living in a waterfront area could be a factor that interact with participants' systems literacy. In this study, Ahmet and Cansu live in waterfront areas, where Eren and Deniz were residences of metropolitan areas. Accordingly, Ahmet and Cansu had richer understanding on the basics of the water system and provided more detail on water system in their hometown.

The possible effects of parental occupations remained open to discussion, even though I provided some indicators for their interference. As provided in the methodology chapter, parental occupation is one of the indicators for socioeconomic status of a family (Aarø et al., 2009; Galobardes et al., 2006) and socioeconomic status is positively correlated with child's academic achievement in Turkey (MoNE, 2018). Within the context of the study, functional systems literacy can be compatible with students' achievement scores since FSL encompasses concepts that is taught in school context. As stated previously, high socioeconomic status is positively correlated with high achievement in Turkey. In a similar manner, Ahmet and Eren were high achiever students and their parental occupations were as one of the indicators for higher socioeconomic status. Thus, having an advanced FSL compared to other cases could be partially explained by their parents' occupations which was also compatible with the previous reports in the literature (e.g. Aarø et al., 2009; Galobardes et al., 2006; MoNE, 2018). On the other hand, it seemed that the interactions of Cansu and Deniz with their parents interfered with their CUSL and CRSL and these interactions might be related to parents' occupations. For example, Cansu had relatively richer CUSL compared to other cases. When her responses were examined, she mentioned her activities in their garden done with her father as well as the effects of her activities on her daily life and her mental model when she reflected her CUSL and CRSL. Thus, as her father was a farmer, it can be inferred that father's occupation interacted with her

CUSL and CRSL. In other words, Cansu's father might be one of the factors that cultivate her cultural and critical systems literacy. Deniz, whose mother was an environmental educator, had responses in CRSL that seemed to be affected by her mother's occupation, but she did not share any specific instance with her mother. However, she revealed her motivational orientation, motive concerns, action strategies, and self-efficacy beliefs more than her peers. Yet, this also needed to further verification.

Another variable, types of high school, was not detected as a factor that interact with students' systems literacy. Instead, participation of extracurricular activities offered by the high school seemed to have an interaction with students' systems literacy which might be classified as a weak interaction. Eren attended seminars of systems science and sustainable development goals. His participation to extracurricular activities seemed to enrich his mental model in terms of FSL. No indicator was found in his responses in CUSL and CRSL regarding extracurricular activities. Cansu attended waste collection event in her village and a water footprint seminar offered by her high school. Her participation seemed to enrich her declarative knowledge in FUSL, declarative and procedural knowledge in CUSL. Moreover, these extracurricular activities seemed to interact with some of the components of CRSL. Ahmet, on the other hand, watched videos related to water issues in Turkey and water footprint. These extracurricular media seemed to enrich his declarative knowledge on FSL. Nonetheless, he stated that he did not integrate this knowledge into his action strategies in his daily life. Deniz exemplified instances from her vacations as well as popular news on the media while she was talking about the basics of her local system. Instead of talking about her residence area, she preferred to reveal her cultural systems literacy at a national scale. Based on their self-reports, we might infer that extracurricular activities remembered easily by the cases, but it seemed that they were not too effective to reflect their behavior.

Apart from these variables, cases frequently mentioned their observations as well as their daily life experiences. This finding could support my initial hypothesis as

children have innate ability for being systems literate. Nevertheless, the analysis of the responses revealed that some of the in-situ answers and alternative conceptions were based on cases' observations and daily life observations. There were also similar findings in the previous studies emphasizing that students have still alternative conceptions derived from observations and daily life experiences (Brody, 1993; Covitt et al., 2009; Gunckel et al., 2012; Osborne and Cosgrove; 1983). Recently, Havu-Nuutinen, Kärkkäinen, and Keinonen (2018) also reported that had already some background knowledge and alternative conceptions which were based on daily life experiences. At this point, it is important to emphasize that their observations and daily life experiences are, of course, important variables but we should be able to trace and monitor their learning based on real life experiences. If their observations and daily life experiences is not monitored, their alternative conceptions and in-situ responses would possibly, in turn, hinder their systems literacy.

Some of the previous studies also highlighted the role of popular media in students' conceptions. For example, Brody (1993) found that students tended to explain the phenomena related to water based on popular media. In a similar vein, Wood (2014) reported that media is one of the sources reported by the students regarding 'water saving tips'. Within the context of the study, all cases exemplified some of the instances from media and internet. However, no specific instance was detected that reflect to their water consumption behavior. For example, Ahmet correctly explained the concept of hidden use of water but his responses in CRSL revealed that he did not integrate this concept into water consumption behavior. What is more, he was amotivated towards efficient water use. Thus, it can be concluded that the role of media could be explored in further studies.

To recap, the definition of systems literacy, its operational definition within the context of the water and potential factors that might interfere with systems literacy were discussed with previous studies in the literature. The summary of this part was visualized in Figure 6.1. In the next section, assumptions and limitations were portrayed.

## 6.4 Assumptions and Limitations

The assumptions are listed as following:

- I assume that water system is one of the systems that human beings are familiar with from their daily life. Therefore, mental models of the individuals related to water system can be acquired even if they are not familiar with the term “system”.
- The concept of water is taught from 3<sup>rd</sup> to 8<sup>th</sup> grade level in schools. In elementary science, social science, life science, and even some cases in mathematics classes, students learn about different features of water. Therefore, I reckon that students have inherently a potential to be a systems literate in water context. However, the levels of systems literacy can vary person to person.
- Water is one of the entities that individuals are engaged in every day in many activities. Hence, daily life experiences with water might be a factor that shape students’ systems literacy in water context.

On the other hand, limitations of the study can be following:

- Multiple case studies include inherently exhaustive amount of data to be reported. This characteristic might interact with researcher’s decision on determining sample size. Even though I tried to include cases with maximum variations, more cases could be added to explore the nature of system literacy in water context.
- This study explores the readiness of the students’ systems literacy in water context. In different contexts, the elements of systems literacy may change. Hence, further studies should consider this aspect.
- In this study, I proposed a map that indicated the interactions among the elements of human system as well as elements of systems literacy. This map was constructed based on the qualitative findings of the study. To propose a model, further quantitative analyses will be required.
- This study was based on students’ self-reported responses. To acquire more accurate data, participants’ water footprint or the amount of water that they use in their daily life water consumption are also needed.

- Even though K-12 studies on water are available in educational literature, comparing the findings of the study based on the notion of systems literacy was a challenging process for me there was no specific study on systems literacy in water context.

## **6.5 Implications and Recommendations**

This study aimed to provide an alternative definition for systems literacy and to explore the readiness of the students completing middle school degree regarding systems literacy in water context. Their systems literacy was examined in three elements as functional, cultural, and critical systems literacy. For the future studies, it can be recommended that these three elements should be included since they are complementary to each other. The combination of the themes and categories within each element can vary in different system contexts as well as in different population characteristics.

Functional and cultural systems literacy were examined through different types of knowledge as well as the nature of the incorrect responses. Elaborating students' factual statements enabled the researcher to gain deeper understanding on their FSL and CUSL. In this sense, determining the nature of FSL and CUSL could provide data for the researchers/educators to reorient their programs or designing interventions to nurture systems literacy of the individuals. Within the context of the study, most of the cases' FSL and CUSL were composed of declarative knowledge. When questions were asked to reveal their procedural knowledge, in-situ responses and alternative conceptions appeared in their responses. Declarative knowledge is also an important element for systems literacy because (1) it encompasses basic knowledge for a system (Ben-Zvi-Assaraf 2010a); and (2) procedural knowledge naturally begins with declarative knowledge (Marzano & Kendall, 2008). However, in order to have an advanced level of systems literacy, individuals should have both declarative and procedural knowledge required to be known for a system. To promote FSL and CUSL of individuals, integrating media (Ferreira da Luz Culpi & Pereira Alves, 2015),

physical models (Duffy, 2012), graphics and diagrams (McTigue & Flowers, 2011) into instruction could be promising. Moreover, as Ben-Zvi Assaraf et al. (2012) denoted, outdoor learning as well as cultural exchange opportunities could provide basis for understanding the water system as a whole.

In addition to types of knowledge, individuals' alternative conceptions and in-situ answers should also be determined to have an accurate systems literacy. Alternative conceptions or misconceptions were detected through the conception test and interview questions in this study. As Bar (1989) denoted in the concept of evaporation, the proportion of selecting the correct answer increased as pupils grow older; however, their alternative conceptions become apparent when students explain the processes occurred in those concepts during the interview. Thus, using more than one data collection tool could have a critical role to detect alternative conceptions or in-situ answers. In the case of administered four-tiered conception test, the findings of this study would be limited. For the further studies, I recommended to use multiple data collection tools to detect alternative conceptions/in-situ answers of the participants. Both quantitative (e.g. multi-tiered conception test) and qualitative data collection tools (e.g. semi-structured interviews) could provide rich information about participants' conceptions. At this point, it is essential to note that alternative conceptions were not disappeared completely (Bar, 1989) even after exposure to teaching (Osborne and Cosgrove, 1983). Nevertheless, diagnosing them lead the researchers, policy makers and educators to find starting point(s) to adjust teaching, teaching materials, programs and also school curricula to meet students' needs. Within the context of water system, I agree with the recommendation of Shepardson and his colleagues (2009) that school curricula should consider the limitations of the students' conceptions and make necessary revisions by means of water cycle, human effect, climate, and climate change as a system rather than including these concepts as 'silos'.

Critical systems literacy could be considered as vital point of systems literacy since it contains not only constructs for advance mechanisms of the system but also developing an individual and public response to sustain the mechanisms of a system. Functional



and cultural systems literacy as well as their interactions also scaffold critical systems literacy. Thus, if individuals did not develop a proper critical systems literacy, it will not be possible to be accurate systems-literature individuals. Cases in this study had limited CRSL based on their either their limited CUSL or FSL. The possible reasons for having limited CRSL, although they are speculative, could be listed as following: (1) cases' alternative conceptions could hinder their potential; (2) our national science curriculum might not provide opportunities to cultivate students' critical systems literacy; or (3) as none of the participant had richer understanding in both CUSL and FSL, cases might not be able to improve their critical systems literacy. The third reason given above requires an additional note. Within the context of the study, the cases had richer understanding either in FSL or CUSL. To be able to have an advanced level of critical systems literacy in water context, one might need both FSL and CUSL. This study revealed that extracurricular activities remembered easily by the cases, but it seemed that they were not too effective to reflect their behavior. At this point, I believe that formal education could nurture students' systems literacy provided that necessary revisions are made to accommodate the notion of systems literacy in curricula. Conventional methods and revisions might not be sufficient to raise systems-literature individuals since they were mainly designed for lectures taught as separate disciplines.

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## A. CONCEPTION TEST AND ANSWER KEY

(Instructions were given verbally before the test)

### KAVRAM TESTİ

#### 1.1 Dünya'daki suyun *büyük* bir kısmı nerede bulunmaktadır?

- a. Buzullarda
- b. Büyük göl ve akarsularda
- c. Yeraltı sularında
- d. Okyanuslarda

#### 1.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

#### 1.3 Yukarıdaki soruya verdiğiniz cevabın *sebebi* nedir?

- a. Su, Dünya'da en çok okyanuslarda bulunmaktadır.
- b. Suyun büyük bir miktarı, yerkabuğunun altında bulunmaktadır.
- c. Su, en fazla donmuş miktarda kutuplarda ve yüksek rakımlarda bulunmaktadır.
- d. Yüzey akış suları bütün tatlı su kaynaklarını toplamaktadır.
- e. Diğer (Lütfen belirtiniz).....

#### 1.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

#### 2.1 Su döngüsündeki suyun hareketinin *sebebi* aşağıdakilerden hangisidir?

- a. Güneşten gelen ısı
- b. Yerçekimi
- c. Ay'ın yerçekimi
- d. Dünya'daki canlılar
- e. a ve b

#### 2.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

#### 2.3 Yukarıdaki soruya verdiğiniz cevabın *sebebi* nedir?

- a. Dünya'daki herhangi bir hareket, Dünya'nın yer çekiminden kaynaklanmaktadır.
- b. Güneş enerjisi, suyun buharlaşarak atmosfere çıkmasını sağlar ve Dünya'nın yerçekimi ise suyu yağışlar sırasında aşağıya doğru geri çeker.
- c. Hem okyanus dalgaları hem de Ay, su döngüsünün hareketinden sorumludur.
- d. Sadece Güneş, suyun Dünya'daki hareketini kontrol eder.
- e. Gökyüzünden yağış şeklinde düşen su, yeryüzündeki canlıların kullanımından sonra atmosfere geri dönmektedir.
- f. Diğer (Lütfen belirtiniz).....

#### 2.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**3.1 Dünya'daki suyun (katı, sıvı ve gaz) toplam miktarı \_\_\_\_\_**

- a. neredeyse sabittir.
- b. sürekli artmaktadır.
- c. sürekli azalmaktadır.
- d. zaman içinde artıp azalmaktadır.

**3.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**3.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Su döngüsü kapalı bir sistem olduğu için herhangi bir su kazancı veya kaybı olmaz.
- b. Su döngüsü açık bir sistem olduğu için suyun toplam miktarı sürekli artıp azalmaktadır.
- c. Su döngüsü açık bir sistem olduğu için suyun bir miktarının yeraltına girmesine olanak tanır.
- d. Su döngüsü açık bir sistem olduğu için suyun belli bir miktarı, su buharı olarak atmosferden uzaya çıkar.
- e. Su döngüsü açık bir sistem olduğu için suyun belli bir miktarı, su buharı olarak uzaydan atmosferimize girer.
- f. Diğer (Lütfen belirtiniz).....

**3.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**4.1 Bulut oluşumu için aşağıdakilerden hangisi gereklidir?**

- a. Su buharı ve atmosferdeki tozlar
- b. Ozon, su buharı ve azot
- c. Alçak hava basıncı ve alçak bağıl nem
- d. Oksijen ve hidrojen

**4.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**4.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Suyun oluşumu için gereken elementler oldukları için
- b. Su damlacıkları, atmosferdeki tozları bir çekirdek gibi kullanarak etrafında yoğunlaşırlar.
- c. Atmosferde bulunan değişik gazlarının etkisi ile oluşur.
- d. Atmosferdeki bazı şartların bulut oluşumu için gerekli olması
- e. Diğer (Lütfen belirtiniz).....

**4.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**5.1 Su döngüsünün gerçekleşmesi için gerekli olan enerjinin büyük bir kısmının kaynağı aşağıdakilerden hangisidir?**

- a. Okyanuslardan
- b. Güneşten
- c. Atmosferden
- d. Dünya'nın çekirdeğinden

**5.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**5.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Atmosferde, sera gazlarından kaynaklanan ısınma süreci su döngüsüne enerji verir.
- b. Dünya'nın çekirdeğindeki ısı enerjisi su döngüsüne enerji sağlar.
- c. Dünya'daki okyanus akıntıları ve dalgalar su döngüsüne enerji sağlar.
- d. Su döngüsü için gerekli olan enerjinin neredeyse tamamı Güneş'ten gelir.
- e. Diğer (Lütfen belirtiniz).....

**5.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**6.1 Hangi süreç, bulut oluşumunu en iyi açıklar?**

- a. Buharlaşma
- b. Yoğuşma
- c. a ve b

**6.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**6.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Yeryüzünden buharlaşan su buharı, bulutlara doğru çıkar.
- b. Yeryüzünden buharlaşan su buharı, atmosferde soğuk hava ile karşılaştığında yoğunlaşarak bulutları oluşturur.
- c. Yeryüzünden buharlaşan su buharı, rüzgâr yardımıyla bulutlara taşınır.
- d. Yeryüzündeki su buharlaşarak bulutları oluşturur.
- e. Diğer (Lütfen belirtiniz).....

**6.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim
- b. Eminim
- c. Emin değilim.
- d. Kesinlikle emin değilim

**7.1 Su döngüsünün bir başlangıç noktası \_\_\_\_\_**

- a. vardır. b. yoktur.

**7.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim b. Eminim c. Emin değilim d. Kesinlikle emin değilim

**7.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Bulutlar su döngüsünün başlangıç noktasıdır.  
b. Su döngüsü, yağışlarla başlayıp buharlaşma ile devam eden bir döngüdür.  
c. Döngülerin bir başlangıç veya bitiş noktası yoktur.  
d. Diğer (Lütfen belirtiniz).....

**7.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim b. Eminim c. Emin değilim d. Kesinlikle emin değilim

**8.1 Aşağıdakilerden hangisini çıkarırsak su döngüsü *durur*?**

- a. Yerçekimi c. Akarsular  
b. İnsan d. Bitkiler

**8.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim b. Eminim c. Emin değilim d. Kesinlikle emin değilim

**8.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Güneş enerjisi ile buharlaşan su, yerçekimi sayesinde yağış olarak yeryüzüne geri döner.  
b. İnsanlar olmasaydı, su döngüsü diye bir şey olmazdı.  
c. Yağışlarla beslenen akarsular, suyu okyanuslara taşıyarak suyun dönmesini sağlarlar.  
d. Bitkiler terleme, fotosentez ve solunum yoluyla su döngüsünün devamlılığını sağlarlar.  
e. Diğer (Lütfen belirtiniz).....

**8.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim b. Eminim c. Emin değilim d. Kesinlikle emin değilim

**9.1 Küresel ısınma su döngüsünü nasıl etkilemektedir?**

- a. Olumlu etkilemektedir.  
b. Olumsuz etkilemektedir.  
c. Herhangi bir etkisi yoktur.

**9.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**



- a. Kesinlikle eminim      b. Eminim      c. Emin değilim      d. Kesinlikle emin değilim

**9.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. Küresel ısınma ile buharlaşma artacağı için sular Dünya'dan gider.
- b. Küresel ısınma, iklim değişikliğinin sebeplerinden biri olduğu için su döngüsü de olumsuz etkilenir.
- c. Buzullar eridiği için Dünya'daki su miktarı artar.
- d. Küresel ısınma sonucu oluşan asit yağmurları, su döngüsünü kirletmektedir.
- e. Küresel ısınma sebebiyle yağışlar artacağı için temiz su kaynakları artacaktır.
- f. Su döngüsü ve küresel ısınma birbirinden farklı kavramlardır.
- g. Diğer (Lütfen belirtiniz) .....

**9.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim      b. Eminim      c. Emin değilim.      d. Kesinlikle emin değilim

**10.1 Su döngüsü ve iklim değişikliği arasında nasıl bir ilişki vardır?**

- a. Herhangi bir ilişki yoktur.
- b. İklim değişikliği, su döngüsünün hızını ve şiddetini değiştirir.
- c. Aralarında doğrusal bir ilişki vardır.

**10.2 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim      b. Eminim      c. Emin değilim.      d. Kesinlikle emin değilim

**10.3 Yukarıdaki soruya verdiğiniz cevabın sebebi nedir?**

- a. İklim değiştikçe buharlaşma hızı değişir. Mesela kış aylarında buharlaşma daha az olur.
- b. İklim değişikliği, su döngüsünü durdurur.
- c. İklim değiştikçe Dünya'daki su artıp azalır. Mesela, yazın su azalırken kışın artar.
- d. İkisi birbirinden farklı kavramlardır.
- e. İklim değişikliği su döngüsü hızlandırır. Bu sebeple, bazı yerlerde sel bazı yerlerde ise kuraklık meydana gelir.
- f. Diğer (Lütfen belirtiniz) .....

**10.4 Yukarıdaki soruya verdiğiniz cevaptan emin misiniz?**

- a. Kesinlikle eminim      b. Eminim      c. Emin değilim.      d. Kesinlikle emin değilim

### ANSWER KEY

| Sub-question<br>Main question | 1 | 2          | 3       | 4          | Status of Response     |
|-------------------------------|---|------------|---------|------------|------------------------|
| 1                             | d | a, b, c, d | a       | a, b, c, d | Correct                |
| 1                             | a | a, b       | c       | a, b       | Alternative Conception |
| 1                             | b | a, b       | d       | a, b       | Alternative Conception |
| 1                             | c | a, b       | b       | a, b       | Alternative Conception |
| 2                             | e | a, b, c, d | b       | a, b, c, d | Correct                |
| 2                             | a | a, b       | d       | a, b       | Alternative Conception |
| 2                             | b | a, b       | a       | a, b       | Alternative Conception |
| 2                             | c | a, b       | c       | a, b       | Alternative Conception |
| 2                             | d | a, b       | e       | a, b       | Alternative Conception |
| 3                             | a | a, b, c, d | a       | a, b, c, d | Correct                |
| 3                             | b | a, b       | e       | a, b       | Alternative Conception |
| 3                             | c | a, b       | c, d    | a, b       | Alternative Conception |
| 3                             | d | a, b       | b       | a, b       | Alternative Conception |
| 4                             | a | a, b, c, d | b       | a, b, c, d | Correct                |
| 4                             | b | a, b       | a, c, d | a, b       | Alternative Conception |
| 4                             | c | a, b       | a, d    | a, b       | Alternative Conception |
| 4                             | d | a, b       | a, c    | a, b       | Alternative Conception |
| 5                             | b | a, b, c, d | d       | a, b, c, d | Correct                |
| 5                             | a | a, b       | c       | a, b       | Alternative Conception |
| 5                             | c | a, b       | a       | a, b       | Alternative Conception |
| 5                             | d | a, b       | b       | a, b       | Alternative Conception |
| 6                             | c | a, b, c, d | b       | a, b, c, d | Correct                |
| 6                             | a | a, b       | b, c, d | a, b       | Alternative Conception |
| 6                             | b | a, b       | d       | a, b       | Alternative Conception |
| 7                             | b | a, b, c, d | c       | a, b, c, d | Correct                |
| 7                             | a | a, b       | a, b    | a, b       | Alternative Conception |
| 8                             | a | a, b, c, d | a       | a, b, c, d | Correct                |

## B. READING TASK

### Gerçek bir hikâye: Havada bir tuhaflık

Geçen ilkbaharda dalları bembeyaz çiçeklerle dolu kiraz ağaçlarında, yaz başında sadece sayılı meyve olması şaşırtıcıydı. Çiçeklerin çoğu meyveye dönerken yanmıştı. Don vurmadığı halde küçücük meyvelerin yanmasına bir anlam veremedik. Nedenini, yıllardır kiraz ağaçlarının bakımını yapan yaşlı bir çiftçiden, tesadüf eseri öğrendik. *“Çiçekler tam meyveye dönerken aniden sağanak yağmur bastırdı. Hemen ardından da kızgın güneş çıktı. Yağmur damlaları merccek oldu, güneş vurunca minicik meyveleri yaktı...”*

İzmir’in güney doğusunda yaşadığım dağ köyünün çevresinde tarımla uğraşanlar, bu yıl meyve ve sebzelerin çoğunun erken olgunlaşıp dalında çürüdüğünü anlatıyorlar günlük sohbetlerimizde. Sonra da ekliyorlar: “Bu yıl havada bir şey var...”

Bu yıl elma da ceviz de üzüm de 15-20 gün erken oldu, Küçük Menderes Havzası’nda. Hem Küçük Menderes Ovası’nda hem de çevresindeki dağlarda, toprağa dayalı üretimle ilgilenen kimle konuştuysam, mevsimlerin 20 gün ilâ 1 ay erken geldiğini söylüyor. Köylülerin Hıdırellez’e, Zemheri’ye göre düzenlediği ekim-dikim takvimi de şaşmış durumda. Örneğin, yüzyıllardır Anadolu halk takvimine göre, insanlar Hıdırellez’de gün doğarken yapraklarda oluşan çiyi toplayarak yoğurt mayalayabiliyordu. Ancak son iki yıldır Hıdırellez zamanı yapraklarda çiy bulamıyoruz. Yaz boyunca hiç yağmur yağmadı. Kasım ayına kadar iki saatten fazla yağmur görmedik. O da sağanak değil, usul usul... Sulamada kullandığımız, dört metre derinlikteki yağmur suyu göletimiz kurumak üzere. Küçük Menderes Ovası’nda tarımla uğraşan arkadaşlarım yer altı suyunun aşırı kullanılması sonucu oluşan boşluklar nedeniyle, derinliği üç metreye varan devasa çökmelerle/obruklarla karşılaştıklarını anlatıyorlar. Yeraltı suyu seviyesi giderek düşüyor.

(retrieved from <https://350turkiye.org/gercek-bir-hikaye-havada-bir-tuhaflik/>)

## C. CODEBOOK

### Categories and Codes of Functional Systems Literacy in Water Context

| Theme - Basics of Water System                                  |                                     |
|-----------------------------------------------------------------|-------------------------------------|
| <i>Category 1: General Characteristics of Water</i>             |                                     |
| FGC11: Quantity of Water                                        | FGC14: Water and Living Organisms   |
| FGC12: Cyclic Nature                                            | FGC15: Relational Responsiveness    |
| FGC13: Properties of Water                                      |                                     |
| <i>Category 2: Power Sources of Water Cycle</i>                 |                                     |
| FPS21: Sun                                                      | FPS23: Gravity                      |
| FPS22: Wind                                                     |                                     |
| <i>Category 3: Components of Water System</i>                   |                                     |
| FC31: Plant                                                     | FC317: Cloud                        |
| FC32: Sun                                                       | FC318: Rain                         |
| FC33: Water                                                     | FC319: Snow                         |
| FC34: Animal                                                    | FC320: Fog                          |
| FC35: Human                                                     | FC321: Hail                         |
| FC36: Ocean                                                     | FC322: Freshwater                   |
| FC37: Sea                                                       | FC323: Ice                          |
| FC38: Water Vapor                                               | FC324: Well                         |
| FC39: River                                                     | FC325: Lake                         |
| FC310: Glacier                                                  | FC326: Stream                       |
| FC311: Spring                                                   | FC327: Dew                          |
| FC312: Soil                                                     | FC328: Algae                        |
| FC313: Wetland                                                  | FC329: Creek                        |
| FC314: Rock                                                     | FC330: Puddle                       |
| FC315: Groundwater                                              | FC331: Mountain                     |
| FC316: Aquifer                                                  |                                     |
| <i>Category 4: Processes of Water System</i>                    |                                     |
| FP41: Evaporation                                               | FP410: Surface flow                 |
| FP42: Condensation                                              | FP411: Melting                      |
| FP43: Sublimation                                               | FP412: Freezing                     |
| FP44: Evapotranspiration                                        | FP413: Frosting                     |
| FP45: Respiration                                               | FP414: Dissolution                  |
| FP46: Precipitation                                             | FP415: Transpiration                |
| FP47: Penetration                                               | FP416: Capillarity                  |
| FP48: Infiltration                                              | FP417: Photosynthesis               |
| FP49: Underground flow                                          |                                     |
| <i>Category 5: Relationship between the Earth (Sub)Systems*</i> |                                     |
| FRES51: Hydrosphere—atmosphere                                  | FRES55: Hydrosphere-anthroposphere  |
| FRES52: Hydrosphere—geosphere                                   | FRES56: Water cycle- nitrogen cycle |
| FRES53: Hydro. (continental)- (marine)                          | FRES57: Water cycle- oxygen cycle   |
| FRES54: Hydrosphere—biosphere                                   | FRES58: Water cycle – carbon cycle  |

\*Any of the triple or more combinations between hydrosphere and the other systems might be observed during data collection

## Categories and Codes of Cultural Systems Literacy in Water Context

| Theme: Basics of Local Water System (LWS)                               |                                       |                                             |
|-------------------------------------------------------------------------|---------------------------------------|---------------------------------------------|
| Category 1: Components of LWS                                           |                                       |                                             |
| CULWS11: Animal                                                         | CULWS14: Microorganisms               | CULWS17: Sewerage System                    |
| CULWS12: Plant                                                          | CULWS15: Local Water Resources        |                                             |
| CULWS13: Human                                                          | CULWS16: Water Supply Network         |                                             |
| Sub-Category 1.1: Local Water Resources                                 |                                       |                                             |
| Sub-Category 1.1.1: Name of LWR                                         |                                       |                                             |
| CUNL1121: Lake Tuz                                                      | CUNL1124: Kurtboğazı Dam              | CUNL1127: River Kızılırmak                  |
| CUNL1122: Lake Mogan                                                    | CUNL1125: Çubuk Dam                   |                                             |
| CUNL1123: Lake Eymir                                                    | CUNL1126: Aegean Sea                  |                                             |
| Sub-Category 1.1.2: Functions of LWR                                    |                                       |                                             |
| CUFL1131: Survival                                                      | CUFL1134: Recreational                | CUFL1137: Energy source                     |
| CUFL1132: Domestic                                                      | CUFL1135: Economical                  | CUFL1138: Religious                         |
| CUFL1133: Agricultural                                                  | CUFL1136: Industrial                  |                                             |
| Sub-Category 1.2: Water Supply Network (WSN)                            |                                       |                                             |
| Sub-Category 1.2.1: Components in WSN                                   |                                       |                                             |
| CUWSNC1211: River                                                       | CUWSNC1218: Dam                       | CUWSNC12115: Home                           |
| CUWSNC1212: Cloud                                                       | CUWSNC1219: Lake                      | CUWSNC12116: People                         |
| CUWSNC1213: Freshwater                                                  | CUWSNC12110: Groundwater              | CUWSNC12117: Sea                            |
| CUWSNC1214: Rain                                                        | CUWSNC12111: Water Storage Facilities | CUWSNC12118: Drinking Water Treatment Plant |
| CUWSNC1215: Snow                                                        | CUWSNC12112: Pipe                     | CUWSNC12119: Well                           |
| CUWSNC1216: Hail                                                        | CUWSNC12113: Engineers                | CUWSNC12120: Fountain                       |
| CUWSNC1217: Water Puddle                                                | CUWSNC12114: Water ATM                |                                             |
| Sub-Category 1.2.2: Processes in WSN                                    |                                       |                                             |
| CUWSNP1221: Precipitation                                               | CUWSNP1223: Water Distribution        |                                             |
| CUWSNP1222: Water Accumulation                                          | CUWSNP1224: Water Treatment           |                                             |
| Sub-Category 1.3: Sewerage System                                       |                                       |                                             |
| Sub-Category 1.3.1: Components in Sewerage System                       |                                       |                                             |
| CUSSC1231: Pipe                                                         | CUSSC1233: Receiving Environment      |                                             |
| CUSSC1232: Wastewater Treatment Plant                                   |                                       |                                             |
| Sub-Category 1.3.2: Processes in Sewerage System                        |                                       |                                             |
| CUWSNP1321: Wastewater Collection                                       | CUWSNP1323: Wastewater Disposal       |                                             |
| CUWSNP1322: Wastewater Treatment                                        |                                       |                                             |
| Category 2: National Water Resources (NWR)                              |                                       |                                             |
| Sub-Category 2.1: Current State of NWR                                  |                                       |                                             |
| CUCSN1311: Water Resources Potential                                    | CUCSN1312: Water Pollution            |                                             |
| Sub-Category 2.2: Name of NWR                                           |                                       |                                             |
| CUNL1321: Aegean Sea                                                    | CUNL1324: Mediterranean Sea           | CUNL1327: Lake Van                          |
| CUNL1322: Black Sea                                                     | CUNL1325: Lake Dipsiz                 |                                             |
| CUNL1323: Marmara Sea                                                   | CUNL1326: Uzungöl                     |                                             |
| Category 3: Relationship among Local, National, and Global (Sub)systems |                                       |                                             |
| CURBS21: LWS- WSN                                                       | CURBS24: LWS -Biosphere               |                                             |
| CURBS22: LWS -Hydrosphere                                               | CURBS25: LWS -Geosphere               |                                             |
| CURBS23: LWS -Atmosphere                                                | CURBS26: LWS - Anthroposphere         |                                             |

## Themes, Categories and Codes of Critical Systems Literacy in Water Context

| Theme 1: Advance Mechanisms in Water System                         |                                         |                 |
|---------------------------------------------------------------------|-----------------------------------------|-----------------|
| Category 1.1: Dynamic Nature of Water System                        |                                         |                 |
| CRDN111: Time Delay                                                 | CRDN112: Redistribution of Water        |                 |
| Category 1.2: Causal Dynamics and Feedback Loops                    |                                         |                 |
| CRFL121: Simple Open Loop                                           | CRFL123: Balancing Loop                 |                 |
| CRFL122: Reinforcing Loop                                           | CRFL124: Open Loop with multiple causes |                 |
| Category 1.3: Evolution of Water System                             |                                         |                 |
| CREV131: Decaying                                                   | CREV133: Toward higher organization     |                 |
| CREV132: Steady state                                               |                                         |                 |
| Category 1.4: Complexity of Water System                            |                                         |                 |
| Sub-Category 1.4.1: Interruptions in the Water System               |                                         |                 |
| CRCO1411: Climate Change                                            | CRCO1412: Hidden Use of Water           |                 |
| Sub-Category 1.4.2: Layers of Complexities                          |                                         |                 |
| CRCO1421: Environmental                                             | CRCO1424: Health                        |                 |
| CRCO1422: Economic                                                  | CRCO1425: Educational                   |                 |
| CRCO1423: Social                                                    | CRCO1426: Governmental                  |                 |
| Theme 2: Invisible Elements of Human System                         |                                         |                 |
| Category 2.1: Beliefs on Water Use                                  |                                         |                 |
| CRBL211: Self-use of water                                          | CRBL213: Sources of Beliefs             |                 |
| CRBL212: Collective use of water                                    |                                         |                 |
| Category 2.2: Self-efficacy towards Efficient Water Use             |                                         |                 |
| CRSE221: High                                                       | CRSE222: Low                            |                 |
| Category 2.3: Motive Concern                                        |                                         |                 |
| CRMC231: Social Altruistic                                          | CRMC233: Biospheric                     |                 |
| CRMC232: Egoistic                                                   |                                         |                 |
| Category 2.4: Action Strategies for Efficient Water Use             |                                         |                 |
| CRAC241: Persuasion                                                 | CRAC244: Reuse of water                 |                 |
| CRAC242: Water loss prevention                                      | CRAC245: Recycle of water               |                 |
| CRAC243: Reduce of water use                                        | CRAC246: No action                      |                 |
| Category 2.5: Emotional response                                    |                                         |                 |
| CREM251: Anger                                                      | CREM253: Happiness                      | CREM255: Apathy |
| CREM252: Sadness                                                    | CREM254: Proud                          |                 |
| Category 2.6: Motivational Orientation for Sustainable Use of Water |                                         |                 |
| CRMO261: Intrinsic motivation                                       | Amotivation                             |                 |
| CRMO262: Extrinsic motivation                                       |                                         |                 |

## D. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARASTIRMA MERKEZİ  
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ  
MIDDLE EAST TECHNICAL UNIVERSITY

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Sayı: 28620816 / 383

22 EKİM 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (IAEK)

İlgili: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Elvan ŞAHİN

Danışmanlığını yaptığınız Sinem DEMİRCİ'nin "Ortaokul ve Lise Öğrencilerinin Su Sistemi Konusundaki Sistemsel Okuryazarlıklarının Belirlenmesi" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve 363 ODTU 2019 protokol numarası ile onaylanmıştır.

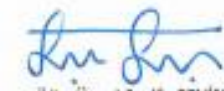
Saygılarımızla bilgilerinize sunarız.

  
Prof. Dr. Tülin GENÇOZ  
Başkan

  
Prof. Dr. Tolga CAN  
Üye

  
Dr. Öğr. Üyesi Ali Emre TURGUT  
Üye

  
Dr. Öğr. Üyesi Muge GÜNDÜZ  
Üye

  
Doç. Dr. Pınar KAYGAN  
Üye

  
Dr. Öğr. Üyesi Şerife SEVİNÇ  
Üye

  
Dr. Öğr. Üyesi Süreyya Özcan KABASAKAL  
Üye



T.C.  
ANKARA VALİLİĞİ  
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.24226161  
Konu : Araştırma İzni

05.12.2019

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE  
(Öğrenci İşleri Daire Başkanlığına)

İlgi : a)MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.  
b)22.11.2019 tarihli ve 165 sayılı yazınız.

Üniversiteniz Matematik ve Fen Bilimleri Eğitimi Anabilim Dalı doktora programı öğrencisi Sinem DEMİRCİ'nin "**Ortaokul ve Lise Öğrencilerinin Su Sistemi Konusundaki Sistemsel Okuryazarlıklarının Belirlenmesi**" konulu çalışması kapsamında ilimize bağlı, ekli listede belirtilen okullarda uygulama talebi ilgi (b) Genelge çerçevesinde incelenmiştir.

Yapılan inceleme sonucunda, söz konusu araştırmanın Müdürlüğümüzde muhafaza edilen ölçme araçlarının; Türkiye Cumhuriyeti Anayasası, Milli Eğitim Temel Kanunu ile Türk Milli Eğitiminin genel amaçlarına uygun olarak, ilgili yasal düzenlemelerde belirtilen ilke, esas ve amaçlara aykırılık teşkil etmeyecek, eğitim-öğretim faaliyetlerini aksatmayacak şekilde okul ve kurum yöneticilerinin sorumluluğunda gönüllülük esasına göre uygulanması Müdürlüğümüze uygun görülmüştür.

Bilgilerinizi ve gereğini rica ederim.

Turan AKPINAR  
Vali a.  
Milli Eğitim Müdürü

Dağıtım:  
Gereği:  
ODTÜ

Bilgi:  
Çankaya, Etimesgut, Polatlı, Sincan  
Pursaklar, Yenimahalle İlçe MEM

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Bilgi için: D. KARAGÜZEL

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Faks: 0 ( )

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## E. SAMPLE PARENT PERMISSION FORM

### Veli Onay Formu

Sevgili Anne/Baba,

Bu çalışma Orta Doğu Teknik Üniversitesi doktora öğrencisi Sinem DEMİRCİ tarafından yürütülmektedir.

**Bu çalışmanın amacı nedir?** Çalışma, ortaokul ve lise öğrencilerinin su sistemi konusundaki sistemsel okuryazarlıklarını belirlemeyi amaçlamaktadır.

**Çocuğunuzun katılımcı olarak ne yapmasını istiyoruz?** : Bu amaç doğrultusunda, çocuğunuzdan verilen kavram testi, çizim etkinliğini ve yarı yapılandırılmış görüşme sorularını cevaplamasını isteyeceğiz ve cevaplarını yazılı ve sözlü olarak toplayacağız. Görüşme esnasında ses kaydı yapılacaktır. Sizden çocuğunuzun katılımcı olmasıyla ilgili izin istediğimiz gibi, çalışmaya başlamadan çocuğunuzdan da sözlü olarak katılımıyla ilgili rızası mutlaka alınacaktır.

**Çocuğunuzdan alınan bilgiler ne amaçla ve nasıl kullanılacak?:** Çocuğunuzdan alacağımız cevaplar tamamen gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Elde edilecek bilgiler sadece bilimsel amaçla kullanılacak, çocuğunuzun ya da sizin ismi ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır.

**Çocuğunuz ya da siz çalışmayı yarıda kesmek isterseniz ne yapmalısınız?:** Katılım sırasında sorulan sorulardan ya da herhangi bir uygulama ile ilgili başka bir nedenden ötürü çocuğunuz kendisini rahatsız hissettiğini belirtirse, ya da kendi belirtmese de araştırmacı çocuğun rahatsız olduğunu öngörürse, çalışmaya sorular tamamlanmadan ve derhal son verilecektir.

**Bu çalışmayla ilgili daha fazla bilgi almak isterseniz:** Çalışmaya katılımınızın sonrasında, bu çalışmayla ilgili sorularınız yazılı biçimde cevaplandırılacaktır. Çalışma hakkında daha fazla bilgi almak için için Matematik ve Fen Bilimleri Eğitimi Bölümü öğretim elemanlarından Araştırma Görevlisi Sinem DEMİRCİ (E-posta: cosinem@metu.edu.tr) ile iletişim kurabilirsiniz. Bu çalışmaya katılımınız için şimdiden teşekkür ederiz.

**Yukarıdaki bilgileri okudum ve çocuğumun bu çalışmada yer almasını onaylıyorum**  
(Lütfen alttaki iki seçenekten birini işaretleyiniz).

**Evet onaylıyorum**\_\_\_\_\_

**Hayır, onaylamıyorum**\_\_\_\_\_

Annenin adı-soyadı: \_\_\_\_\_

Bugünün Tarihi: \_\_\_\_\_

Çocuğun adı soyadı ve doğum tarihi: \_\_\_\_\_

(Formu doldurup imzaladıktan sonra araştırmacıya ulaştırınız).

## F. CURRICULUM VITAE

### PERSONAL INFORMATION

Surname, Name: Demirci, Sinem

e-mail address: cosinemdemirci@gmail.com

### EDUCATION INFORMATION

| Degree | Institution                                                                    | Year of Graduation |
|--------|--------------------------------------------------------------------------------|--------------------|
| Ph.D.  | Elementary Education, Middle East Technical University                         | 2021               |
| MS     | Statistics, Middle East Technical University                                   | 2018               |
| MS     | Elementary Science and Mathematics Education, Middle East Technical University | 2014               |
| BS     | Elementary Science Education, Middle East Technical University                 | 2011               |

### PROFESSIONAL EXPERIENCE

|            |                                  |                    |
|------------|----------------------------------|--------------------|
| 2013- 2020 | Middle East Technical University | Research Assistant |
|------------|----------------------------------|--------------------|

**RESEARCH INTERESTS:** Education for Sustainability, Systems Thinking, Science Education, Teacher Education, Large Scale Assessments in Education, Educational Statistics

**FOREIGN LANGUAGES:** English (Advanced), German (Intermediate)

**COMPUTER SKILLS:** Microsoft Office (Advanced), IBM SPSS Software (Advanced), The R Project for Statistical Computing (Intermediate), LISREL (Intermediate)

## WORKSHOP

|      |                                                                                                                   |                  |
|------|-------------------------------------------------------------------------------------------------------------------|------------------|
| 2012 | Grundtvig Workshop: “Creating Bridge - Education for Sustainable Development ESD in MAB BRs and Designated Areas” | Athens, Greece   |
| 2013 | Climate Reality Project- Climate Change Leadership Corps                                                          | Istanbul, Turkey |
| 2017 | MeWeWhole Multiplier Events- Turkey                                                                               | Ankara, Turkey   |

## AWARD

|      |                                           |                              |
|------|-------------------------------------------|------------------------------|
| 2021 | European Educational Research Association | Bursary Winner for ECER 2020 |
| 2015 | Middle East Technical University          | Thesis of the Year           |

## PUBLICATIONS

### Publications

Demirci, S. & Şahin, E. (2018). An analysis of Turkish middle school science education program placing climate change issues in the context of education for sustainable development. *International Journal of Quality in Education*, 2(1), 13-21.

Demirci, S. (2018). The context of sustainable development in Turkish elementary science curriculum. *International Journal of Quality in Education*, 1(1), 54-61.

Demirci, S. & Teksöz, G. (2017). Self-Efficacy beliefs on integrating sustainability into profession and daily life: in the words of university students. *International Electronic Journal of Environmental Education*, 7(2), 116-133.

Demirci, S., Yılmaz, A., & Şahin, E. (2016). Lise ve üniversite öğrencilerinin atomun yapısı ile ilgili zihinsel modellerine genel bir bakış. *Türkiye Kimya Derneği Dergisi, Kısım C: Kimya Eğitimi*, 1(1), 87-106.

### National and International Conference Presentations

Demirci, S., Şahin E. & Teksöz, G. *Eight-Graders’ Understanding of Hidden Use of Water and Their Action Strategies for Sustainable Use of Water*. Paper will be

- presented at European Conference on Educational Research, Geneva, Switzerland (2021, September)
- Demirci, S., Şahin E. & Teksöz, G. *Middle School Students' Perceptions on the Interactions among Water Cycle, Global Warming, and Climate Change*. Paper will be presented at European Conference on Educational Research, Geneva, Switzerland (2021, September)
- Demirci, S., Şahin E. & Teksöz, G. *Redefining Urbanization: in the views of university students*. Paper presented online at 5<sup>th</sup> International Symposium on Environment and Morals, Turkey (2020, September)
- Demirci, S. & Teksöz, G. *Pre-service Teachers' Perceptions on the Interactions between COVID-19 Pandemic and the Environment*. Paper presented online at 5<sup>th</sup> International Symposium on Environment and Morals, Turkey (2020, September)
- Demirci, S. & Teksöz, G. (2018). *Pre-service Science Teachers' Skills on Problem/Issue Analysis in Environmental Education*. Paper presented at ERPA International Congresses on Education, Istanbul, Turkey (2018, June)
- Demirci, S. *Middle School Students' Mental Models of the Water Cycle*. Paper presented at ERPA International Congresses on Education, Istanbul, Turkey (2018, June)
- Teksöz, G. & Demirci, S. *About the Context of Climate Change Education for Sustainability: In the Words of University Students*. Paper presented at 12<sup>th</sup> Biannual Conference of the European Science Research Association (ESERA), Dublin, Republic of Ireland. (2017, August)
- Demirci, S., Kaplan, G., Cengizoğlu, S., & Şen, M. (2017). *Pre-service teachers' Understandings of sustainability based on ontological entities*. Paper presented at 26<sup>th</sup> International Conference on Educational Sciences, Antalya, Türkiye. (2017 April).
- Cengizoğlu, S & Demirci, S. *Türkiye'de Yaşayan Çocuklar ve Çevre-İnsan İlişkisi: Bir İçerik Analizi Çalışması*. Paper presented at UFBMEK 2016, Trabzon, Türkiye. (2016, September)
- Demirci, S. & Cengizoğlu, S. *Türkiye'de Okul Öncesi Dönemde Fen Eğitimi'nde Yapılan Çalışmaların Bölgelere, Değişkenlere ve Örneklem Gruplarına Göre İçerik Analizi*. Poster presented at UFBMEK 2016, Trabzon, Türkiye. (2016, September)

- Demirci, S. & Şahin E. *An Analysis of Turkish Middle School Science Education Program Placing Climate Change Issues in The Context of Education for Sustainable Development*. Paper presented at the 14<sup>th</sup> International JTEFS/BBCC Conference Sustainable Development, Culture, Education: Innovations and Challenges of Teacher Education for Sustainable Development, Konya, Turkey. (2016, May)
- Demirci, S. *The Context of Sustainable Development in Turkish Elementary Science Curriculum*. Paper presented at the 14<sup>th</sup> International JTEFS/BBCC Conference Sustainable Development, Culture, Education: Innovations and Challenges of Teacher Education for Sustainable Development, Konya, Turkey. (2016, May)
- Demirci, S. & Şen, M. *Pre-Service Science Teachers' Misconceptions About Density and Buoyancy*. Paper presented at the annual meeting of NARST International Conference toward Equity and Justice: Many Different Voices, Cultures, and Languages in Science Education Research for Quality Science Learning and Teaching, Baltimore, Maryland, U.S.A. (2016, April)
- Demirci, S., Şahin E. & Teksöz, G. *Is the Carrying Capacity Exceeded? Preservice Teachers' Beliefs on Human Population Growth*. Paper presented at the annual meeting of North American Association in Environmental Education, San Diego, California, U.S.A. (2015, October)
- Demirci, S., Şahin, E. & Yılmaz, A. *The Effects of History of Science on Students' Mental Models Regarding Atomic Models*. 11<sup>th</sup> biannual Conference of the European Science Research Association (ESERA), Helsinki, Finland. (2015, September)
- Yılmaz, A., Şahin, E. & Demirci, S. *Lise ve Üniversite Öğrencilerinin Atomun Yapısı ile İlgili Zihinsel Modellerine Genel Bir Bakış*. 4. Ulusal Kimya Eğitimi Kongresi, Balıkesir, Turkey. (2015, September)
- Demirci, S. & Şen, M. *Fen Bilgisi Öğretmen Adaylarının Yoğunluk Konusunda Kavram Yanılgılarının Belirlenmesi*. 2. Ulusal Fizik Eğitimi Kongresi, Ankara, Turkey. (2015, September)
- Demirci, S., Şahin E. & Teksöz, G. *An Exploration of University Students' Beliefs on the Sustainable Growth of Human Population*. Paper presented at the 8<sup>th</sup> World Environmental Education Congress (WEEC), Gothenburg, Sweden. (June, 2015)
- Demirci, S. & Teksöz, G. *ESD in Higher Education: University students' perceptions of sustainability and its relation to their self-efficacy beliefs to integrate*

*sustainability into their profession and daily lives.* Poster presented at the Pathways to the Future: Education for Sustainable Development, Tallinn, Estonia. (2015, April).

Şahin, E., Yılmaz. A & Demirci, S. *A Review of Elementary Students' Conceptual Understandings of 'Atom.* Paper presented at the International Organization for Science and Technology Education (IOSTE), İstanbul, Turkey. (2015, April)

Demirci, S. & Teksöz, G. *Üniversite Öğrencilerinin Sürdürülebilir Kalkınma Kavramını Gelecekteki Meslekleri Ve Günlük Yaşamlarına Birleştirmek Konusundaki Öz-yeterlik İnanışları.* Paper presented at the UFBMEK 2014, Adana, Türkiye. (2014, September)

Demirci, S., Şahin E. & Teksöz, G. *What does a Survey Study on Beliefs towards Human Population Growth Imply for Teacher Education?* Paper presented at the EJER 2014 Congress, İstanbul, Türkiye. (2014, April)

Demirci, S., Şahin E. & Teksöz, G. *Determining Pre-service Teachers' Beliefs towards Human Population Growth.* Paper presented at the annual meeting of North American Association in Environmental Education, Baltimore, Maryland, U.S.A. (2013, October)

Çokoğlu, S. & Şahin, E. *Beliefs toward Population Growth in Turkey.* Paper presented at the 1. Ulusal Disiplinlerarası Çevre Kongresi, Sakarya, Türkiye. (2012, May).

## **PROJECT EXPERIENCE**

*Project title:* From Waste to Fertilizer 3 - Composting

*PI:* Assoc. Dr. Serap Bilen (METU, Society and Science Application and Research Center) *Supported by:* TÜBİTAK

*Role & time spent:* Trainer, 19.04.2019 -08.04.2019

*Project No:* 218B226

*Project title:* From Waste to Fertilizer 1 - Composting

*PI:* Assoc. Dr. Serap Bilen (METU, Society and Science Application and Research Center) *Supported by:* TÜBİTAK

*Role & time spent:* Trainer, 09.10.2017 -30.10.2017

*Project No:* 117B056

*Project title:* In-service Science Teachers' Teaching Experiences on Atomic Models within the context of History of Science

*PI:* Assoc. Prof. Dr. Elvan ŞAHİN (METU, Dept. of Science and Mathematics Education) *Supported by:* BAP, METU  
*Role & time spent:* Researcher, 1.1.2015 -31.12.2015  
*Project No:* BAP-05-06-2015-001

*Project title:* University Students' Beliefs on Human Population Growth  
*PI:* Assoc. Prof. Dr. Elvan ŞAHİN (METU, Dept. of Science and Mathematics Education) *Supported by:* BAP, METU  
*Role & time spent:* Researcher, 1.1.2013 -31.12.2013  
*Project No:* BAP-07-03-2013-010

### **COURSES ASSISTED**

Advanced Educational Research  
Environmental Sciences  
Climate Change Education for Sustainability  
Education and Awareness for Sustainability  
Laboratory Applications in Environmental Education  
Skills on Environmental Issue Investigation  
Quantitative Data Analysis in Education  
Measurement and Assessment  
Probability and Statistics  
Practice Teaching in Elementary Education  
Community Service  
Maternal and Child Nutrition

### **ACTIVITIES AND COMMUNITY SERVICE**

Jury Member at Science Fair, ODTÜ Geliştirme Vakfı Okulları, Ankara, Turkey,  
Member of METU Scouts, Ankara, Turkey, 2006-...  
Leader of METU Scouts, Ankara, Turkey, 2009-2011.  
Head of Education Committee at METU Scouts, 2009-2010  
Youth Summer Camp Leader at Middle East Technical University, Ankara, Turkey,  
2009  
Volunteer at Project of Collecting, Sorting, and Recycling Waste “*Temiz Eymir*”,  
Ankara, Turkey, 2008-2010  
Volunteer at annual charity events for suburban elementary school students in Ankara,  
Turkey, 2006-2011.

### **PERSONAL INTERESTS**

Scouting, Pilates, Western concert flute (beginner)

## G. TURKISH SUMMARY / TRKE ZET

### 1. Giriř

Eđitim alanındaki herhangi bir srete rol alan bireyler, eđitimin asıl amacının ne olduđunu srekli sorgularlar. İlk bakıřta bu soru kulađa tuhaf gelmektedir, zira eđitim srelerinde rol alan bireylerin buna bir cevap verebileceđi varsayılır. Ancak, soru ok basit, yalın ve anlařılır grnmesine rađmen cevabı/cevapları olduka karmařıktır.

Eđitimin amacı ile ilgili birok dalda kapsayıcı cevaplar mevcut olsa da *okuryazarlık* (r. Dillon, 2009; Orr, 1994) ve *davranıř deđiřtirme* (r. Hungerford & Volk, 1990) kavramları en sık kullanılan terimler arasındadır. Eđitimin her kademesinde mevcut olan amalardan bir tanesi okuryazarlık seviyesini ykseltmektir (UNESCO, 2000; UNESCO, 2006). Okuryazarlık en temel olarak, yazı dilinin iptidai seviyede zmlenme ve algılanma becerisi olarak tanımlanmaktadır (Kaestle, 1985). Bařka bir deyiřle, yazılı kelimelere bakarak sesli syleme ve anlama becerisidir. Ancak, zaman ierisinde okuryazarlık tanımı evrimleřmekte ve farklı kollara ayrılmaktadır. rneđin, William ve Sniper (1990) okuryazarlık kavramını incelemiř ve bu kavramı  ana unsur erevesinde yeniden yorumlamıřtır. Bu unsurlar *iřlevsel okuryazarlık*, *kltrel okuryazarlık* ve *eleřtirel okuryazarlık* olarak sıralanmıřtır. Bu řekilde yeniden yorumlanan okuryazarlık kavramları, eđitimin amaları arasında tamamlayıcı rol oynayarak alan yazını ierisinde yerini almıřtır (r. DeBoer; 2000; Dillon, 2009).

Eđitimin temel amacını keřfetme abaları, tarih ierisinde konu ile ilgili bilgi birikiminin artması ve okuryazarlık tanımları ile ilgili tartıřmalar okuryazarlık alan yazınının geliřmesinde ciddi katkılar sađlamıřtır. Geleneksel olarak tanımlanmasının yanı sıra, okuryazarlık kavramı bařka bađlamlar ierisinde kullanılarak birok alanda yeniden yorumlanmıřtır (Kaestle, 1985). Dolayısıyla, zaman ierisinde *bilimsel okuryazarlık* (r. Mun vd., 2015; Roberts, 2007b), *evre okuryazarlıđı* (r. Hollweg



vd., 2011; Stables & Bishop, 2001), *sürdürülebilirlik okuryazarlığı* (ör. Nolet, 2009; Winter & Cotton, 2012) gibi bağlamsal okuryazarlık tanımları ortaya konmuş ve teorik çerçeveleri oluşturulmuştur. Ek olarak, diğer sosyal bilimler branşlarında olduğu gibi, bu tanımlar üzerine bir görüş birliğine varılamamıştır. Mevcut çalışma kapsamında ise, bir eğitim araştırmacısı gözünden *sistem okuryazarlığı* kavramı ele alınmıştır.

### **1.1. Sistem, Sistem Bilimleri, Sistemsel Düşünme ve Sistem Okuryazarlığı Kavramlarına Genel Bir Bakış**

Sistem kavramının ortaya çıkışı 18. yüzyıla dayanmaktadır (Reynolds, 2011). Immanuel Kant, o yıllarda sistem fikrini *Saf Aklın Eleştirisi* adlı kitabında ilk olarak tanıtmıştır. Sistem bilimleri kavramının temelleri ise 20. yüzyılın başlarında (Hammond, 2003), bilimin indirgemeci yaklaşımları sorgulanmaya başladığında atılmıştır (Mobus ve Kalton, 2015). 1920'li yıllarda, von Bertalanffy genel sistemler teorisi çerçevesinde yaşayan organizmaların elemanlarının, sadece mekanik etkileşimleri ile açıklanamayacak yapılar olduğu fikri ile ortaya çıkmıştır (Mobus ve Kalton, 2015). Özellikle İkinci Dünya Savaşı sonrasında, sistem teorisi evrimleşmeye ve farklı disiplinlerin içine (ekoloji, sosyal bilimler, işletme vb.) dahil edilmeye başlanmıştır. Eşzamanlı olarak da sistemsel düşünme kavramı, sistem ve sistem bilimleri ile gelişmeye başlamıştır. Sistemsel düşünme kavramı, farklı disiplinlerdeki bilim insanlarının sistemlerin çalışma prensiplerini inceleme ihtiyacının oluşması ve sistem kavramı ile yeni bir söylem gelişmesi üzerine şekillenen bir kavram olmuştur (Hieronymi, 2013).

Sistem bilimleri ve sistemsel düşünme kavramlarının güncel tanımlamaları, birçok farklı akademik disiplinin özellikle son yüzyılda katkı sağladığı çıktılar olarak düşünülebilir (Mobus ve Kalton, 2015). Bu kapsamda, eğitim alanında yapılan sistemsel düşünme çalışmalarında bazı sistem bilimleri prensiplerine rastlamak mümkündür (ör. Ben-Zvi Assaraf & Orion, 2005a; Feriver, Olgan & Teksöz, 2019; Nolet, 2009). Sistem bilimcilerden farklı olarak eğitim alanında çalışan araştırmacılar farklı düzeylerdeki bireylerin sistemleri nasıl algıladıklarını; bu algıları üzerinden

onların sistemlerle olan ilişkilerinin nasıl şekillendiğini (Henning & Chen, 2012) ve sistemsel düşünme kavramını bu bağlamda eğitim alanında nasıl kullanılabileceğini anlamaya çalışmaktadırlar.

Sistemsel düşünme kavramı, aynı zamanda fen eğitiminde bilimsel okuryazarlık başlığı altında bir eleman olarak (Mun vd., 2015) ve sürdürülebilir kalkınma için eğitim kapsamında bir yeterlik olarak (UNECE, 2011; Wiek vd., 2011) ve sürdürülebilirlik okuryazarlık kavramının bir elementi olarak ele alınmaktadır. Bunun ötesinde, 21. yüzyıldaki meselelerin nedenlerini ve sonuçlarını anlamak ve gezegenin sürdürülebilirliğini sağlamak için sistemsel düşünme yaklaşımına ihtiyaç duyulmaktadır (Richmond, 1993). Bu sebeple sistemsel düşünme kavramı eğitim bağlamında önemli bir yere sahiptir. Ancak, sistemsel düşünme kavramının elemanları ve sistem bilimlerinin doğası incelendiğinde, bu çalışmayı yürüten araştırmacı sistemsel düşünme kavramının düşünme sürecinin çok ötesinde yer aldığını savunmaktadır. Bu kavram, sistemler hakkında düşünmenin yanı sıra birtakım becerilere ve yeterlikler de içermektedir ve bu durum sistemsel düşünmeyi “düşünme” eyleminin ötesine taşımaktadır. Ayrıca sistemsel düşünme, *inanışlar*, *amaçlar* ve *değerler* gibi görünmez unsurlara sahip olan insan sistemleri ile kesişmektedir (Henning & Chen, 2012). Buna bağlı olarak, sistemsel düşünme kavramını sistem okuryazarlığı çerçevesinde yeniden yorumlamak bize eğitim bağlamında 21. yüzyıl meseleleri ile nasıl başa çıkacağımız konusunda yeni rotalar çizme imkânı sağlama potansiyeli bulunmaktadır.

Sistem bilimleri alan yazınındaki mevcut çalışmaların büyük bir kısmı sistemsel düşünme kavramını içerse de sistem okuryazarlığı kavramı 2000’li yılların başından itibaren telaffuz edilmeye başlanmıştır. Bu kavram ile ilgili ortaya atılan ilk düşünce ise 90’lı yıllarda İngiltere’de ortaya çıkmıştır (Reynolds, 2011). O yıllarda sistem okuryazarlığı şu şekilde ifade edilmiştir: “Sistemsel düşünme, modern dünyanın en temel okuryazarlıklarından bir tanesidir.” (Reynolds, 2011, p.40). Wood (2011) ise sistem okuryazarlığını şöyle tanımlamıştır: “Sistem okuryazarlığı, sosyal tarih ve kültürel söylem çalışmaları ile ekosistem süreçlerini teknik olarak anlama becerisini

birleştiren bir kavramdır” (s.4-5). Sweeney (2012) ise sistem okuryazarlığı nosyonunu eğitim bağlamında inceleyen öncülerden bir tanesidir. Sweeney sistem okuryazarlığı kavramını ‘karmaşık ilişkiler hakkındaki bilgi seviyesi’ olarak ifade etmiştir. Sistem okuryazarlığı kapsamında sistem okuryazarı olarak tanımlanan bireyler bir olay veya olgudaki çoklu nedenselliklerini görme becerisine sahiptir. Ayrıca sistem okuryazarı bireyler su, hava ve toprak gibi kamusal mülkiyetlerin önemini kavrama becerisine sahiptirler. Sweeney’e göre birçok çocuk sistem davranışlarını formal bir eğitim almadan görme becerisine doğuştan sahiptir. Dolayısıyla, çocukların sistem okuryazarlığını geliştirmek adına günlük hayat bağlamını kullanmak oldukça basit bir yöntemdir.

Özetle, sistem kavramının ortaya çıkışı beraberinde yeni alanların da ortaya çıkmasına sebep olmuştur (sistem teorileri, sistemsal düşünme, sistem okuyazarlığı vb.). Sistem okuryazarlığı kavramları arasında, sadece Wood’un çalışması (2011) kültürel elementleri içermektedir. Diğer tanımlar ise genel olarak bireylerin bilişsel düzeylerine odaklanmaktadır. Halbuki, Stables ve Bishop’un da ifade ettiği gibi (2001), okuryazarlık tanımları işevuruk olarak yapılmakta ve birçoğu okuryazarlıkla ilgili önemli argümanları içermemektedir. Bu sebeple bu tanımların, okuryazarlık teorik çerçevesi felsefi açıdan eksik yönleri bulunmaktadır. Bu eksiklikler de ilgili alan yazınında gelişmeyi ve ilerlemeyi sınırlandırmaktadır. O nedenle, mevcut çalışmanın araştırmacısı bu eleştirileri dikkate alarak sistem okuryazarlığı kavramına alternatif bir model oluşturmayı hedeflemiştir.

## **1.2.Globalleşmenin Mihenk Taşları, Eğitim ve Sistem Okuryazarlığı**

Sistem okuryazarlığına duyulan ihtiyacı anlamak için, insanlık tarihinde özellikle sanayi devrimi sonrasında bilim ve teknoloji alanındaki mihenk taşlarını incelemek yararlı olabilir. Bu mihenk taşları bir yandan politika, ekonomi ve sosyal hem olumlu hem de olumsuz etkilere sebep olurken (Al-Rodhan & Stoudmann, 2006) diğer taraftan da fen eğitimine (DeBoer, 2000) ve diğer eğitim alanlarına yeni bakış açısı kazandırmışlardır (Merriman & Nicoletti, 2007; Orr, 2004). Ek olarak, mihenk

taşlarının çevreye verdiği olumsuz etkiler de (Alagiri & Kumar, 2012; Al-Rodhan & Stoudmann, 2006) eğitim gündemini şekillendirmede önemli bir rol oynamıştır (Orr, 2004; Tilbury, 1995; United Nations, 1992).

Günümüzde, öğrenciler indirgemeci yaklaşımı destekleyen ve tekil disiplinlerde uzmanlaşmayı destekleyen bir anlayışla yetiştirilmektedir (Strachan, 2009). Halbuki içinde yaşadığımız gezegen bir sistemdir ve bu sistemin devamlılığını sürdüren döngülerle çalışmaktadır. Bu bağlamda, fen eğitimi ve okuryazarlık bağlamları bu mekanizmaları kısmen içerse de 21. yüzyılda yaşadığımız küresel problemlerin etkisini hala tecrübe etmekte olmamız aslında sistemlerin çalışma prensiplerini etkili bir şekilde eğitim yoluyla aktaramadığımız olasılığını önümüze çıkarmaktadır. Bu sebeple, eğitimin amacı ile ilgili yapılan tartışmalar (DeBoer; 2000; Dewey, 1934; Dillon, 2009; Hungerford & Volk, 1990), mihenk taşlarının çevreye, ekonomiye, topluma ve gelişmeye olan etkileri (Al-Rodhan & Stoudmann, 2006), bağlam temelli okuryazarlık tanımları (McBeth et al., 2006; Mun et al., 2015; Parkin et al., 2004), 21. yüzyılda küresel olarak karşılaşılan problemler (Pouloupoulos, 2016; Rieuwerts, 2015; Wilson & Stevenson, 2016) ve sistem bilimleri ve sistemsel düşünme bakış açıları (Ben-Zvi Assaraf & Orion, 2005a; Mobus & Kalton, 2015) bütüncül olarak ele alındığında, bireylerin içinde bulundukları dünyayı bir sistem olarak algılama ve 21. yüzyıl küresel problemlerine uzun vadeli çözümler sunabilme becerilerine sahip olmaları gerektiği sonucuna varılabilir.

Doğal kaynakların yok edilmesi, insan nüfus artışı ile birlikte artan kirlilik problemleri, aşırı tüketim davranış kalıpları ve temel çevre felaketleri, insanlığı bu konular önlem almaya teşvik etmiş ve bunların sonucunda etkileri azaltmak ve uyum sağlamak adına birtakım girişimlerde bulunulmuştur (Alagiri & Kumar, 2012). Bu girişimle aynı zamanda eğitim ve bağlam temelli okuryazarlık kavramları üzerinde hem direkt hem de dolaylı yoldan birtakım etkiler bırakmıştır. Uzun vadeli sistemlerle ilgili arayış hala sürse de eğitim sistemi bu etkileri önlemek veya yavaşlatmak yolunda kritik bir unsur olarak görülmektedir. Fakat mevcut eğitim sistemi, sistemleri parçalarına ayırarak analiz etmeye ve sistem mekanizmasını parçaları inceleyerek anlamaya çalışan bir

anlayış sistemine sahiptir (Orr, 2004). Ancak, Capra'nın da ifade ettiđi gibi (Capra, 1996) bütün parçaların toplamından daha fazlasıdır ve sistemleri parçalarına ayırarak anlamaya çalışmak o sistemlerin bazı özelliklerinin anlaşılmasına sebebiyet verme potansiyeline sahiptir. Dolayısıyla, eğitimdeki indirgemeci yaklaşımın hegemonyası, sistemleri anlama yolculuğunda bizi sekteye uğratmaktadır.

Ison ve Shelley (2016) sistem okuryazarlığı ve sistemsel düşünme kavramlarının eğitim gündeminde olmamasının sistem okuryazarı bireyler yetiştirme konusunda sınırlılığa yol açtığına vurgu yapmaktadır. Bu sebeple, eğitimciler ve sosyal bilimciler olarak odak noktamızı parçalara ayrılmış sistemlerden bütüncül olarak irdedeceğimiz sistem anlayışlarına çevirmemiz gerektiğı açıktır. Bu noktada, alan yazınındaki sistem okuryazarlık kavramlarını incelemek ve kavramsal bir model oluşturup alternatif bir sistem okuryazarlığı tanımı yapmak bir başlangıç noktası olarak belirlenebilir.

### **1.3.Çalışmanın Amaçları, Araştırma Soruları ve Önemi**

Yukarıdaki bilgiler ve tartışmalar göz önünde bulundurularak mevcut çalışmanın amaçları (1) 'sistem okuryazarlığı' tanımına kavramsal bir model oluşturmak; (2) sistem okuryazarlığı kavramına su sistemi bağlamında bir alternatif çerçeve önermek; (3) su sistemi kapsamında tanımlanan sistem okuryazarlığı ile etkileşen olası faktörleri belirlemek ve (4) ortaokulu bitirmiş öğrencilerin su sistemi kapsamında sistem okuryazarlıkları ile ilgili hazırbulunuşluk seviyelerini tespit etmek olarak belirlenmiştir. Bu kapsamda araştırma soruları aşağıdaki gibi belirlenmiştir:

- 1) Sistem okuryazarlığı nedir?
  - a. Sistem okuryazarlığının unsurları nelerdir?
- 2) Ortaokul derecesini tamamlamış öğrenciler için sistem okuryazarlığı kavramının su sistemi bağlamında alternatif çerçevesi nedir?

- a. Ortaokul derecesini tamamlamış öğrenciler için işlevsel sistem okuryazarlığı kavramının su sistemi bağlamında alternatif çerçevesi nedir?
  - b. Ortaokul derecesini tamamlamış öğrenciler için kültürel sistem okuryazarlığı kavramının su sistemi bağlamında alternatif çerçevesi nedir?
  - c. Ortaokul derecesini tamamlamış öğrenciler için eleştirel sistem okuryazarlığı kavramının su sistemi bağlamında alternatif çerçevesi nedir?
  - d. Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki sistem okuryazarlıklarının unsurları arasındaki etkileşim örüntüleri nelerdir?
- 3) Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki sistem okuryazarlığı ile ilgili hazırbulunuşluk seviyeleri nelerdir?
- a. Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki işlevsel sistem okuryazarlığı ile ilgili hazırbulunuşluk seviyeleri nelerdir?
  - b. Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki kültürel sistem okuryazarlığı ile ilgili hazırbulunuşluk seviyeleri nelerdir?
  - c. Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki eleştirel sistem okuryazarlığı ile ilgili hazırbulunuşluk seviyeleri nelerdir?
  - d. Öğrencilerin alternatif kavramları su sistemi bağlamındaki sistem okuryazarlık seviyeleri ile nasıl etkileşmektedir?
- 4) Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki sistem okuryazarlığı hazırbulunuşlukları ile ilişkisi bulunan olası etkenler nelerdir?
- a. Su sistemi bağlamında ele alınan sistem okuryazarlığı kavramı cinsiyet, başarı seviyesi, yaşanılan yer, ebeveyn mesleği ve lise türleri değişkenleri ile nasıl bir değişim göstermektedir?

- b. Ortaokul derecesini tamamlamış öğrencilerin su sistemi bağlamındaki sistem okuryazarlıklarını etkileyen diğer etkenler nelerdir?

İlgili alan yazını ve araştırma soruları çerçevesinde mevcut çalışmanın önemi birkaç noktada özetlenebilir. Öncelikle yaşadığımız evren bir sistemdir ve bu sistemin içinde çok fazla sayıda sistem olarak da nitelendirebileceğimiz alt sistemler bulunmaktadır (Mobus & Kalton, 2015). Ancak, fen eğitiminin güncel durumu, bu sistemleri parçalarına ayırarak parçaları inceleme şeklinde eğitim programlarına entegre etme eğilimindedir (Colucci-Gray, 2019; Orr, 2004). Bu bakış açısı ile yetiştirilen öğrenciler indirgemeci bir yaklaşımı benimseyerek sistemlerin içindeki veya arasındaki etkileşimleri ve karmaşık yapıyı anlayacak beceriye sahip olamayabilir. Öte yandan, sistem teorileri ve sistem bilimleri bilimin birçok farklı dalına entegre edilerek ilgili bilim dallarına oldukça kullanışlı çıkarımlar sağlamaktadır. Bu noktada fen eğitimi sistem ve sistem bilimleri bakış açısı ile kalibre etmek, 21. yüzyılda tecrübe ettiğimiz küresel problemleri anlayan ve onlara çözüm üreten sistem okuryazarı bireyler yetiştirme hususunda imkân tanıyabilir. Öte yandan sistem okuryazarlığı ile ilgili alan yazınında sistem okuryazarlığı çalışmalarını geliştirmek ve katkı sağlamak adına bilimsel çalışmalar yürütme çağrısı yapılmaktadır (ör. Dubberly, 2015; Tuddenham, 2017). Bu noktada, sistem okuryazarlığı kavramını fen eğitimi bağlamında yeniden tanımlamak ve öğrencilerin mevcut hazırbulunuşluk seviyelerini belirlemek eğitim alanında katkı sağlama potansiyeline sahiptir. Dolayısıyla, mevcut çalışma araştırmacılara, eğitimcilere ve eğitim politikacılarına mevcut fen eğitimi gündemini nasıl revize edileceği hususunda bir bakış açısı kazandırabilir.

Fen eğitiminin yanı sıra, sistem bilimleri yapı ve içerik bakımında sürdürülebilir kalkınma için eğitim alanı ile de uyumlu bir yapıya sahiptir. Mobus ve Kalton (2015) bu durumu şöyle özetlemektedir: “Sistem bilimleri; geleneksel olarak ayrı akademik disiplinler olarak nitelendirilen doğa bilimleri ve beşerî bilimler arasındaki kesişimi birleştirme potansiyeline sahiptir. Bu akademik disiplinler, 21. yüzyılın en temel sorusu ve engeli olan sürdürülebilirlik anlayışının ortaya çıkması ile ivedilikle bir araya gelmiştir” (p.10). Bu sebeple, insanlığın sürdürülebilirlik kavramını sistem

prensipieri çerçevesinde anlayıp yorumlayan ve 21. yüzyıl sorunlarına adaptasyon ve çözüm süreçlerini geliştiren bireylere ihtiyacı olduğu açıktır. Fen eğitiminin yanı sıra, sürdürülebilir kalkınma için eğitim de bireylerin bu yolda ihtiyaç duydukları bilgi, beceri, tutum ve değerleri kazandırabilen bir yapıya sahiptir (UNESCO, 2015). Ek olarak, sürdürülebilir kalkınma için eğitim çalışmaları doğası gereği sürdürülebilirlik okuryazarlığı (Nolet, 2009) ve sistemsel düşünme (Sterling, 2003) bağlamlarını içeren bir yapıya sahiptir. Bu sebeple, mevcut çalışmanın amacı sürdürülebilir kalkınma için eğitim çalışmalarına da katkı sunma potansiyeline sahiptir. Sistem okuryazarlığı kavramını sürdürülebilir kalkınma için eğitim bağlamına entegre etmek sürdürülebilir kalkınma nosyonuna başka bir bakış açısı kazandırabilir.

İçinde yaşadığımız gezegendeki su sistemi, bu çalışmanın bağlamı olarak birçok sebepten ötürü seçilmiştir. Öncelikle su kavramı fen bilgisi, sosyal bilgiler, yabancı dil ve hatta matematik gibi farklı ortaokul derslerinin içinde yer almaktadır (MoNE, 2020). Öte yandan, revize edilmiş fen eğitimi müfredatı sürdürülebilir kalkınma için eğitim nosyonunu hem direkt hem de dolaylı yoldan su ile ilgili olan ünitelerin içinde yer vermektedir. Dolayısıyla, ortaokul derecesini bitirmiş Türk öğrencilerden fen eğitimi ve sürdürülebilir kalkınma için eğitim bağlamlarında su ile ilgili belirli anlayışları geliştirmeleri beklenmektedir. Bu özellikler, su sistemini öğrencilerin sistem okuryazarlıklarını keşfetme hususunda uygun bir bağlam yapmaktadır. Bir diğer husus ise su kavramının iklim ve hava durumu Sadler, Nguyen, & Lankford, 2017), doğal döngülerin arasındaki kompleks yapı ve bağlantılar (Brody, 1993), su kullanımının çevreye (Österlind & Haldén, 2007), ekonomiye (Wood, 2014; DeLorme, Hagen, & Stout, 2003) ve topluma (Wood, 2014) etkileri gibi üst düzey kavramlara temel oluşturmasıdır. Fakat, farklı ülkelerde yürütülen alan yazını çalışmaları öğrencilerin su ve su kavramı ile ilgili konularda iptidai bir anlayış sergilediklerini göstermektedir (Ben-Zvi-Assaraf & Orion, 2005a; Covitt, Gunckel, & Anderson, 2009). Dolayısıyla, öğrencilerin su bağlamındaki sistem okuryazarlıklarını keşfetmek onların su ile ilgili zihinsel modellerini nasıl oluşturduklarına ve bu zihinsel modellerin nasıl etkileştikğine dair bilgi sağlayarak alan yazınına katkıda bulunabilir.



UNESCO'nun raporuna göre (2015), çoğu ülkede su eğitimi ile ilgili durumun yetersiz olduğunu ortaya koymaktadır. UNESCO bu durumun sebebinin öğrencilerin başarı seviyelerine odaklanması olduğunu savunmaktadır. Schaap ve van Steenberg'in de iddia ettiği gibi (2001), su ile ilgili meselelerde bilgi seviyesi dışında tutum, beceri ve davranışların da hesaba katılması ve incelenmesi gerekmektedir. Bu sayede öğrenciler hem yerel hem de küresel ölçekteki su krizlerini anlama ve teorik bilgilerini günlük hayatlarına transfer etme hususunda kendilerini geliştirme imkânı bulabilirler. Bu noktada, ortaokul öğrencilerinin hazırbulunuşluklarını belirlemek için su sistemini seçmek yukarıda bahsedilen yapılarla ilgili çalışmalara da katkı sağlayabilir çünkü öğrencilerin halihazırda su, su döngüsü, küresel ve yerel ölçekte insan su kullanımının etkileri, su tüketimi ile ilgili tutum ve davranış kalıpları ile ilgili kavrayışlara sahip oldukları düşünülmektedir. Öğrencilerin su sistemi bağlamındaki hazırbulunuşluklarını belirlemek, ülkelerin su eğitimi ile ilgili programlarını gözden geçirme noktasında yolu açabilir. Bu sayede, bilgi seviyesine ek olarak hangi yapıları entegre etmemiz gerektiği konusunda da bizlere yol gösterebilir.

Sistem okuryazarlığı ile etkileşime giren olası faktörleri belirlemek, sistem okuryazarlığı kavramını anlamak ve derinleştirmek konusundaki anlayışı yükseltebilir. Su ile ilgili yapılan geçmiş çalışmalarda bazı faktörler araştırmacılar tarafından raporlanmıştır. Bu faktörlerden bazıları bilişsel farklılıklar (Ben-Zvi-Assaraf & Orion, 2005a), kitle iletişim araçları (Wood, 2014), aile (Aarø et al., 2009) ve günlük yaşam tecrübeleri (Havu-Nuutinen, Kärkkäinen & Keinonen, 2018) olarak belirlenmiştir. Listelenen bu faktörleri mevcut çalışmanın kapsamına almak ve sistem okuryazarlığı kapsamında yeniden incelemek su sistemi bağlamındaki sistem okuryazarlığı yapısı hakkında fikir edinmemizi sağlayabilir.

Çalışmanın hedefi ortaokulu bitirmiş öğrencilerin sistem okuryazarlığı üzerine olduğu için katılımcı olarak 9. sınıflar olarak belirlenmiştir. Bu sınıf seviyesinin seçilmesinin sebebi su kavramının ortaokul fen eğitimi programında 8. sınıf ikinci döneminin sonuna kadar devam ediyor olmasıdır. 9. sınıfın ilk döneminde ise öğrenciler ortaokul eğitim programını tamamladıkları için verdikleri bilgiler ortaokul eğitim

programındaki su kavramın ele alış biçiminin sistem okuryazarlığını nasıl şekillendirdiği konusunda yol gösterici olacaktır. Öte yandan, su sistemi, su döngüsü konusu dışında, farklı derslerde birbirinden ayrı olarak işlenmektedir. Bu indirgemeci yaklaşımın sistem okuryazarlığı üzerindeki etkisini görmemize olanak sağlayacaktır. Uzun vadede, bu çalışmanın araştırmacılara ve program geliştirmecilere ortaokul öğrencilerinin sistem okuryazarlığı ile ilgili hazırbulunuşlukları konusunda önemli ipuçları sağlama potansiyeline sahiptir.

## 2. Yöntem

Bu bağlamda hem kavramsal hem de deneysel araştırma basamaklarını içeren bir araştırma döngüsü tasarlanmıştır. Kavramsal araştırma çerçevesinde, ‘felsefi kavramsallaştırma’ ve ‘kavramsal sistemler’ metodolojileri kullanılmıştır. Oluşturan kavramsal model ve teorik çerçeveleri test etmek ve detaylı bilgi elde etmek adına nitel bir araştırma yöntemi olan çoklu durum çalışması seçilmiştir. Araştırmaya dokuzuncu sınıf seviyesinde dört lise öğrencisi katılmıştır. Çalışmanın verileri dört aşamalı kavram testi, iki adet çizim etkinliği ve yarı yapılandırılmış görüşme soruları ile toplanmıştır.

Meredith’e göre (1993), araştırma yapma döngüsü tanımlayıcı modellerin teori olarak adlandırılana kadar doğrulanması, gözden geçirilmesi veya yanlışlanması gereken kavramsal çerçevelere dönüştüğü, sürekli olarak tekerrür eden bir olgudur. Bu döngüde, kavramsal araştırma metodu tanımlama ve açıklamalara dayalı olan bir yöntem olarak araştırma döngüsü içerisinde yerini almaktadır. Bu kısmın araştırma döngüsüne dahil edilmemesi çalışmaların dışsal geçerliliklerini azaltan bir durum olarak nitelendirilmektedir.

Mevcut çalışmada, felsefi kavramsallaştırma metodolojisi sistem okuryazarlığı kavramına (1) bağlam temelli okuryazarlıkları karşılaştırarak; (2) ilave kavramlar, yapılar ve ilişkiler ekleyerek mevcut sistem okuryazarlığı tanımlarına alternatif bir

çerçeve sunmak amacıyla kullanılmıştır. Bu adımları takip ederek araştırmacı, sistem okuryazarlığı için bir kavramsal model oluşturmuştur.

Kavramsal modeller farklı ilişkileri içeren kavramlar ve yapılardan oluşuyorsa, kavramsal çerçeve olarak isimlendirilirler (Meredith, 1993). Kavramsal çerçeveler, teorilere temel oluşturma potansiyeline sahip önteoriler olarak anılmaktadırlar. Bu çerçeveler, araştırmacılara yapılar arasındaki ilişkileri kavrama ve kurulan hipotezleri test etme adına önemli bilgiler sağlamaktadırlar. Mevcut çalışmadaki kavramsal modelin açıklama kapasitesini arttırmak adına bir kavramsal çerçeve metodolojisi olan kavramsal sistemler yöntemi de çalışmaya dahil edilmiştir. Oluşturulan kavramsal çerçeve bulgular bölümünde verilecektir.

Oluşturulan bu model ve çerçeveleri test etmek ve geçerli teoriler oluşturmak için araştırma döngüsünde deneysel araştırma kısmına ihtiyaç vardır (Meredith, 1993). Bu argümandan yola çıkarak mevcut çalışma deneysel bir araştırma yöntemi olan nitel araştırma desenini çalışmaya dahil etmiştir. Deneysel bulgulara dayanarak, su sistemi bağlamındaki sistem okuryazarlığı için oluşturulan alternatif çerçeve araştırma döngüsü kapsamında yeniden yorumlanmıştır.

## **2.1.Çalışmanın Örneklemi**

Merriam (2009), amaçlı örnekleme yönteminin nitel çalışmalarda genel olarak yer verildiğini rapor etmiştir. Patton (2015) tarafından da ifade edildiği üzere, küçük örneklemlerde genelleme mümkün olmasa da amaçlı örneklem yöntemi ile oluşturulan örneklemlerden elde edilen bilgiler gelecekteki çalışmalara çok detaylı bilgi sunması sebebiyle bir bakış açısı kazandırma potansiyeline sahiptir. Bu tip katılımcılar bilgi bakımından zengin olan katılımcılar olarak adlandırılmaktadır (Merriam & Tisdell, 2016; Patton, 2015). Mevcut çalışmanın bağlamında, nitel amaçlı örnekleme yöntemi yukarıda belirtilen sebepler nedeniyle kullanılmıştır. Çalışmanın bağlamı kapsamında seçilen katılımcılardan sistem okuryazarlığı ile ilgili detaylı bilgi elde etmek ve olası bileşenlerini belirlemek amaçlanmıştır. Bu sebeple, katılımcıları seçmeden önce

alınacak bilgileri maksimize etmek için birtakım seçme kriterleri araştırmacı tarafından listelenmiştir. Bu kriterler (1) 9. Sınıf öğrencisi olma; (2) farklı lise türlerinde öğrenim görme ve (3) lise öncesi yaşadıkları yerin herhangi bir su kaynağının yakınında/uzağında yer alma olarak belirlenmiştir.

Çalışmanın amacında ortaokulu bitirmiş öğrencilerin sistem okuryazarlıkları olduğu için, katılımcıların 9. sınıfın ilk döneminde olmasına dikkat edilmiştir. Bu sınıf seviyesinin seçilmesinin sebepleri pilot çalışmada ifade edilmiştir. Okul seçimi hususunda hem özel hem de devlet lisesi öğrencilerini dahil edilirken aynı zamanda fen lisesi, sosyal bilimler lisesi gibi farklı okul türlerinin de olmasına dikkat edilerek katılımcılar arasındaki değişkenliğin farklı olmasına dikkat edilmiştir. Üçüncü kriter olan lise öncesi ikamet edilen yer öğrencilerin su kaynakları ile günlük hayatlarındaki etkileşimin su sistemi bağlamındaki sistem okuryazarlıklarını nasıl şekillendirdiği ile ilgili bilgi toplama amaçlanmıştır. Bu kritere paralel olarak değişik yerlerde yaşayan öğrenciler (deniz kıyısı, nehir kenarı, su kenarında olmayan iç kesimler vb.) çalışmaya dahil edilmiştir. Kısaca, üç farklı seçim kriteri veri toplama öncesinde belirlenmiştir. Sonuç olarak, dört farklı katılımcı çalışmanın örneklemini oluşturmuştur. Katılımcılar ile ilgili genel bilgiler Tablo 1’de özetlenmiştir.

## **2.2.Veri Toplama Araçları**

Çalışma kapsamında beş adet ölçüm aracı araştırmacı tarafından geliştirilmiştir. Geliştirilen ölçüm araçları hem uzman görüşüne sunulmuş hem de pilot çalışmada test edilmiştir. Ölçüm araçlarından ilki 4 aşamalı kavram testidir. Kavram testi ile katılımcıların işlevsel sistem okuryazarlıklarının ölçülmesi hedeflenmiştir. Öte yandan, iki adet çizim etkinliği oluşturulmuştur. Bunlardan ilki ile işlevsel sistem okuryazarlık seviyeleri ölçülürken ikinci çizim etkinliği ile kültürel okuryazarlıkları hakkında göstergeler elde edilmesi planlanmıştır. Yarı yapılandırılmış görüşmeler de dört aşamada gerçekleştirilmiş olup sistem okuryazarlığının üç elementi de irdelenmiştir. Gerçek bir hikâyeye dayanan hikâye etkinliği ile de eleştirel sistem

okuryazarlık hakkında veri toplama amaçlanmıştır. Tablo 2’de ölçüm araçları ve sistem okuryazarlık bileşenleri listelenmektedir.

**Tablo 1.**

*Katılımcılar ile ilgili Genel Bilgiler*

| <b>Katılımcı<br/>ve<br/>Doğum<br/>Tarihi</b> | <b>Persentil</b> | <b>Okul<br/>Türü</b>         | <b>Evin<br/>Konumu</b>                 | <b>Ebeveyn<br/>Meslekleri</b>              | <b>Müfredat<br/>Dışı<br/>Etkinliklere<br/>Katılımı</b>                                                                                                                                                                                 |
|----------------------------------------------|------------------|------------------------------|----------------------------------------|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Eren<br>(2005)                               | 1.               | Fen<br>Lisesi                | Su<br>kıyısında<br>olmayan<br>bir kent | Baba: Doktor<br>Anne: Mühendis             | -Sistem<br>Bilimleri<br>Semineri<br>- SK<br>Amaçları<br>Semineri<br>- Fizik<br>Projesi<br>- Bilim<br>Olimpiyatları<br>-Kızılırmak<br>Çöp<br>Toplama<br>Etkinliği<br>- Su Ayakizi<br>Semineri<br>- Su Ayakizi<br>ile ilgili<br>Videolar |
| Cansu<br>(2003)                              | 18.              | Sosyal<br>Bilimler<br>Lisesi | Nehir<br>kıyısında<br>bir göl          | Baba: İşçi<br>Anne: Aşçı                   |                                                                                                                                                                                                                                        |
| Ahmet<br>(2005)                              | 6.               | Özel<br>Okul                 | Deniz<br>kenarında<br>bir şehir        | Baba:<br>Akademisyen<br>Anne: Avukat       |                                                                                                                                                                                                                                        |
| Deniz<br>(2005)                              | 15.              | Özel<br>Okul                 | Su<br>kıyısında<br>olmayan<br>bir kent | Baba: Bankacı<br>Anne: Çevre<br>Eğitimcisi | -Okul<br>Sonrası<br>Başarılı<br>Öğrenciler<br>için Açılan<br>Ek Derslere<br>Katılım                                                                                                                                                    |

**Tablo 2***Veri Toplama Araçları ve İlgili Sistem Okuryazarlık Kategorileri*

| <b>Veri Toplama Aracı</b>                   | <b>Sistem Okuryazarlığı Elementi</b> | <b>Sistem Okuryazarlığı Kategorileri</b>                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Kavram Testi                                | İşlevsel Sistem Okuryazarlığı        | Suyun Genel Özellikleri<br>Su Döngüsünün Güç Kaynakları<br>Gezegendeki Sistemler Arasındaki İlişkiler                                                                                                                                                                                                                                                                                                      |
| 1. Çizim Etkinliği                          | İşlevsel Sistem Okuryazarlığı        | Suyun Genel Özellikleri<br>Su Döngüsünün Güç Kaynakları<br>Su Döngüsünün Elementleri ve Süreçleri<br>Gezegendeki Sistemler Arasındaki İlişkiler                                                                                                                                                                                                                                                            |
| 2. Çizim Etkinliği                          | Kültürel Sistem Okuryazarlığı        | Yerel Su Sisteminin Bileşenleri<br>Yerel Su Sisteminin Etkileşimleri                                                                                                                                                                                                                                                                                                                                       |
| Gerçek bir Hikâyeye Dayanan Okuma Etkinliği | Eleştirel Sistem Okuryazarlığı       | Su Sisteminin Dinamik Doğası<br>Nedensel Dinamikler ve Geri Besleme Döngüleri<br>Su Sisteminin Karmaşık Yapısı                                                                                                                                                                                                                                                                                             |
| Yarı yapılandırılmış görüşmeler             | İşlevsel Sistem Okuryazarlığı        | Suyun Genel Özellikleri<br>Su Döngüsünün Güç Kaynakları<br>Su Döngüsünün Elementleri ve Süreçleri<br>Gezegendeki Sistemler Arasındaki İlişkiler                                                                                                                                                                                                                                                            |
|                                             | Kültürel Sistem Okuryazarlığı        | Yerel Su Sisteminin Bileşenleri<br>Ulusal Su Kaynakları<br>Yerel Su Sisteminin Etkileşimleri                                                                                                                                                                                                                                                                                                               |
|                                             | Eleştirel Sistem Okuryazarlığı       | Su Sisteminin Dinamik Doğası<br>Nedensel Dinamikler ve Geri Besleme Döngüleri<br>Su Sisteminin Evrimsel Durumu<br>Su Sisteminin Karmaşık Yapısı<br>Su Kullanımı ile ilgili İnanışlar<br>Verimli Su Kullanımına Yönelik Özyeterlik İnanışları<br>Endişe Gerekçeleri<br>Verimli Su Kullanımı ile ilgili Eylem Planları<br>Duygusal Tepkiler<br>Sürdürülebilir Su Kullanımı ile ilgili Motivasyon Yönelimleri |

### 2.3.Verİ Toplama Süreci

Veri toplama süreci 2019-2020 akademik yılının güz döneminde gerçekleşmiştir. Üniversitenin etik kurulundan gerekli izinler alındıktan sonra ayrıca Milli eğitim Bakanlığı'ndan etik izni alınmıştır. Daha sonra, katılımcıları belirlemek için okullarla ve ailelerle görüşülmüştür. Devlet okulundan seçilen katılımcıların belirlenmesinde okul yönetimi de rehberlik etmiştir. Okul yönetimine seçme kriterleri belirtilerek uygun öğrenci seçimi konusunda öneride bulunmaları istenmiştir. Öte yandan, özel okulda öğrenim gören katılımcılar araştırmacının iletişim açısından belirlenmiştir. Seçme kriterleri baz alınarak katılımcı seçildiği için amaçlı örneklem yöntemi kullanılmıştır. Bütün katılımcılar ve ebeveynleri çalışmanın amacı ile ilgili bilgilendirilmiş ve bunun sonucunda çalışmaya gönüllü olanlardan veri toplanmıştır.

Her bir katılımcı ile iki oturum yapılarak veri toplanmıştır. Bütün görüşmeler yüz yüze araştırmacı tarafından yapılmıştır ve araştırmacı görüşmeleri tek başına gerçekleştirmiştir. İlk oturumda, bütün katılımcılar ilk olarak su döngüsü çizdikleri 1. çizim etkinliğini tamamlamışlardır. Daha sonrasında araştırmacı, katılımcılardan çizdikleri şekli açıklamalarını istemiştir. Açıklamalar esnasında ilgili noktalarda ek sorular sorulmuştur. Bu etkinlik tamamlandıktan sonra kavram testine geçilmiştir. İlk oturumun sıralaması bütün katılımcılarda, kavram testinin çizim etkinliğine etki etmemesi adına aynı şekilde izlenmiştir. Kavram testinin ardından, katılımcıların yerel sus sistemi ile ilgili olan 2. çizim etkinliği yapılarak ilk oturum sonlanmıştır. 1. çizim etkinliğinin aksine, 2. çizim etkinliği bazı noktalarda soru-cevap şeklinde ilerlemiş ve katılımcılar oturum boyunca çizimleri ile ilgili güncelleme yapabilme erişimine sahip olmuşlardır. İlk oturum ortalama 50 dakika sürmüştür.

İkinci oturumdan önce, araştırmacı kavram testi cevaplarını ve çizimleri inceleyerek anlaşılmayan kısımlar için ek sorular hazırlamıştır. Ayrıca, görüşme kayıtlarını yazılı olarak transkript ederek ikinci oturuma hazırlanmıştır. İkinci oturumda, katılımcıların zihinsel şemalarını ortaya koymak ve katılımcıların su tüketim davranışlarını belirlemek için yarı yapılandırılmış görüşme yapmıştır. Görüşmelerin üçüncü fazı tamamlandıktan sonra gerçek bir hikâyeye dayanan okuma etkinliği yapılmıştır.

Öğrenciler hikâyeyi okuduktan sonra hikayedeki olay örgüsü üzerin yarı yapılandırılmış görüşmelerin dördüncü aşaması gerçekleşmiştir. İkinci oturum ortalama 45 dakika sürmüştür.

Veri toplama esnasında öğrencilerden demografik bilgiler de toplanmıştır. Her iki oturum da aynı koşullar altında gerçekleştirilmiş olup öncesinde çevresel şartların uygunluğu (ışık, havalandırma, sıcaklık vb.) kontrol edilmiştir. Tüm veri toplama süreci katılımcıların bilgisi dahilinde sesli olarak kayıt altına alınmıştır.

## **2.4. Veri Analizi**

Araştırma döngüsü içerisinde hem kavramsal araştırma hem de deneysel araştırmanın verileri analiz edilmiştir. Bu bölümde, her iki kısımda da veri analizinde izlenen yöntemler özetlenmiştir.

### *2.4.1. Kavramsal Araştırma Veri Analizi*

İçerik analizi yazılı belgelerin analiz edilmesi olarak basitçe tanımlanabilir (Patton, 2002). Bu çalışmada, içerik analizi önceki bağlam temelli çalışmaların önemli noktalarını özetlemen adına kullanılmıştır. İçinde sistem kavramını barındıran bilimsel okuryazarlık, çevresel okuryazarlık, sürdürülebilirlik okuryazarlığı, sistem okuryazarlığı ve sistemsel düşünme çalışmaları analiz etme sürecine dahil edilmiştir. Bu kapsamda, ortak özellikler ve farklılıklar listelenmiş, olası kavram veya yapıların eklenip eklenmemesi hususunda gerekli çıkarımlar alan yazınına dayanarak eleştirel olarak yapılmıştır. Bu çalışmaların özeti ve olası eklemeler tezin ikinci bölümünde ayrıntılı olarak ele alınmıştır. Öte yandan, önerilen kavramsal çerçeve bulgular kısmında belirtilmiştir.

### *2.4.2. Deneysel Araştırma Veri Analizi*

4 aşamalı kavram testi, çizim etkinlikleri ve yarı yapılandırılmış görüşme soruları bu çalışma bağlamında çok veri kaynağı olarak nitelendirilmiştir. Kavram testinin cevapları, (1) doğru cevap; (2) yanlış sebepli doğru cevap; (3) doğru sebepli yanlış



cevap; (4) alternatif kavram ve (5) bilmiyor şeklinde kodlanmıştır. Bu kombinasyonlar ve cevap anahtarları Appendix A’da verilmiştir. Diğer taraftan, nitel veriler araştırma süresi boyunca tekrar ederek analiz edilmiştir. Örneğin, ilk oturum yapılırken ilgili yerlere notlar alınmış, ikinci oturumu gerçekleştirmeden önce ilk oturumun transkripti yapılmış, kavram testi okunmuş ve anlaşılmayan noktalar için yeni görüşme soruları eklenmiştir. Transkriptler ve notlar alınırken, iptidai analizler yapılmıştır. İkinci oturum sonrası transkriptler tamamlanmış, verilerin tamamının bir kopyası yazılı olarak çıktı alınmış diğer kopyası bulut programlarından birine yüklenmiştir. Bütün bu süreç her katılımcı için tekrarlanmıştır.

Özetle, birden fazla analiz yöntemi mevcut çalışma için kullanılmıştır. Veri analiz çeşitleri ve amaçları aşağıdaki figürde özetlenmiştir.

**Figür 1.**

*Çalışmada Kullanılan Veri Analizi Çeşitleri*



## 2.5.Çalışmanın Geçerliği ve Güvenilirliği

Mevcut çalışmanın geçerliği ve güvenilirliğini sağlamak adına inandırıcılık, aktarılabilirlik ve tutarlılık ölçütleri ile ilgili göstergeler toplanmıştır. Çalışmanın inandırıcılığı ile ilgili uzun süreli etkileşim, veri çeşitlemesi, uzman incelemesi ve araştırmacının düşünümseelliği yöntemleri kullanılarak birtakım göstergeler elde edilmiştir. Çalışmanın aktarılabilirliğini sağlamak adına ayrıntılı betimleme ve amaçlı örnekleme yöntemleri uygulanmıştır. Çalışmanın tutarlılığını sağlamak adına tutarlılık incelemesi hem araştırmacının iç tutarlılığı hem de uzman incelemesi uygulanmıştır.

## 3. Bulgular

Kavramsal araştırmanın sonuçlarına dayanarak sistem okuryazarlığı kavramı tanımlanmıştır. Ardından su sistemi bağlamında sistem okuryazarlığı kavramı ile ilgili bir teorik çerçeve sunulmuştur.

### 3.1. Sistem Okuryazarlığı Nedir?

Sistem okuryazarlığı tanımları araştırmacı tarafından şu şekilde tanımlanmıştır:

Sistem okuryazarlığı etkileşimde bulunduğumuz sistemleri ve o sistemleri etkileyen eylemlerimizi algılama biçimi ile ilgilidir. Bu algı sadece genel sistem prensipleri ile ilgili bilgi düzeyini kapsamaz, aynı zamanda kültürel etmenleri ve sistem davranışlarını anlamaya ve sistem okuryazarı olmaya ilişkin diğer yapıları da içerir. Tipik bir sistem okuryazarı bireyden, yeterli düzeyde işlevsel ve kültürel sistem okuryazarlığına dayanan bir eleştirel sistem okuryazarlığı seviyesine sahip olması beklenir. Bunun da ötesinde, sistem okuryazarı bireyler, insanların birer sistem olarak hem sistem mekanizmalarını hem de bireysel ve kolektif davranışları etkileme konusunda potansiyele sahip olduklarının bilincine varmış bireylerdir.

Stables'ın (1998) teorik çerçevesiyle uyumlu olarak, sistem okuryazarlığı kavramı işlevsel sistem okuryazarlığı, kültürel sistem okuryazarlığı ve eleştirel sistem okuryazarlığı olarak üç bileşen altında tanımlanmış ve detaylandırılmıştır. İleriki kısımlarda bu bileşenlerin tanımları verilmektedir.

#### 3.1.1. İşlevsel Sistem Okuryazarlığı

Yukarıdaki tanıma paralel olarak, araştırmacı işlevsel sistem okuryazarlığı tanımını şu şekilde yapmıştır: işlevsel sistem okuryazarlığına sahip bireylerden sadece bir sistemi direkt ya da dolaylı yoldan tanımlaması değil, aynı zamanda içinde yaşadığı ve bir parçası olduğu sistemi ya da sistemleri tanılaması beklenmektedir. Bu bireyler aynı zamanda sistemlerin diğer küçük alt sistemlerden oluştuğu çıkarımını yapma ve bu sistemler tarafından organize edilen ve çalıştırılan bileşenleri, süreçleri ve ilişkilerini açıklama becerisine sahip olmalıdır. Ek olarak, işlevsel sistem okuryazarı olan bireyler sistem içindeki ilişkiler ağını çizerek gösterebilmeli veya bununla ilgili bir görseli yorumlayarak ilişkileri açıklayabilmelidir. Aynı zamanda, sistemlerin sürekli bir evrim geçirme halinde bulunduğu bilgiyi işleme, alma ve gönderme özelliklerine sahip olduklarını ifade etmelidirler. Bütün bunları yaparken, bireylerden sistemin devamlılığı veya sistem evrim süreçleri için herhangi bir çıkarım yapmaları beklenmemektedir.

### *3.1.2. Kültürel Sistem Okuryazarlığı*

Mevcut çalışma kapsamında, araştırmacı kültürel sistem okuryazarlığını şöyle tanımlamıştır: kültürel sistem okuryazarlığına sahip bireylerden içinde yaşadıkları yerel sadece bir sistemi direkt ya da dolaylı yoldan tanımlaması değil, aynı zamanda içinde o sistemi ya da sistemleri tanılaması beklenmektedir. Bu bireyler aynı zamanda yerel bağlamdaki sistemlerin diğer küçük alt sistemlerden oluştuğu çıkarımını yapma ve bu sistemler tarafından organize edilen ve çalıştırılan bileşenleri, süreçleri ve ilişkilerini açıklama becerisine sahip olmalıdır. Ek olarak, kültürel sistem okuryazarı olan bireyler sistem içindeki ilişkiler ağını çizerek gösterebilmeli veya bununla ilgili bir görseli yorumlayarak ilişkileri açıklayabilmelidir. Bütün bunları yaparken, bireylerden yerel sistemin devamlılığı veya sistem evrim süreçleri ile ilgili herhangi bir çıkarım yapmaları beklenmemektedir.

### *3.1.3. Eleştirel Sistem Okuryazarlığı*

Stables (1998), eleştirel sistem okuryazarlığının hem işlevsel hem de kültürel sistem okuryazarlığı dayanarak oluştuğunu savunmaktadır. Benzer şekilde, araştırmacı

eleştire sistem okuryazarlığını Stables'ın argümanına dayanarak kurgulamıştır. Mevcut çalışma kapsamında, bireylerin eleştirel sistem okuryazarlığına sahip olması için hem işlevsel hem de kültürel sistem okuryazarlıkları seviyelerinin yeterli düzeyde olması gerekmektedir. Bu önkoşulun dışında, yeterli düzeyde eleştirel sistem okuryazarı olan bireylerin (1) sistem dinamiklerini çoklu zaman düzeyinde algılaması; (2) farklı zaman ölçeklerinin sistem dinamiklerine olan olası etkilerinin farkında olması; (3) farklı tür ve seviyelerdeki karmaşıklık düzeylerinin sistemlerde aksamalara ve hatalara sebep olacağını açıklaması; (4) sistemlerdeki evrim mekanizmalarının ileri, geri veya sabit olarak çalıştığını açıklaması; (5) geri besleme döngülerini açıklaması veya çizmesi; (6) sistemlerin diğer sistemlere ait modelleri içerdiği çıkarımını yapması; (7) herhangi bir karmaşık uyarlanabilir sistemin kendi modelini içermesi potansiyelini kavraması ve farklı zihinsel modellerin insan-doğa ilişkisine müdahale edebileceğini tahmin etmesi ve (8) sistemlerin anlaşılabilir ve geliştirilebilir yapılar olduğunu kavraması beklenmektedir. Bunların ötesinde, insan sisteminin görünmeyen bileşenlerinin bireylerin sistem okuryazarlıklarına potansiyel etkilerinin olduğu bazı özellikler bulunmaktadır. Bunun sonucunda, inanış, eylem stratejileri, öz-yeterlik inanışları, endişe gerekçeleri, duygusal tepkileri ve motivasyon yönelimleri de olası yapılar olarak eleştirel sistem okuryazarlığı başlığı altında yer almaktadır. Yukarıda bahsedilen sistem okuryazarlığı ile ilgili kavramsal model Figür 2'de görselleştirilmiştir.

### **3.2.Ortaokul Derecesini Tamamlamış Öğrenciler için Su Sistemi Bağlamında Sistem Okuryazarlık Alternatif Çerçevesi Nedir?**

Mevcut çalışmanın ikinci araştırma sorusu kapsamında ortaokul derecesini tamamlamış öğrenciler için su sistemi bağlamındaki sistem okuryazarlık kavramı ile ilgili bir tanım daha yapılmış ve alternatif çerçeve sunulmuştur. Sistem okuryazarlığı ve üç bileşeni ile ilgili bir önceki bölümdeki tanımlara uygun olarak su sistemi bağlamında tanımlar yapılmıştır. Ayrıca sistem genel prensipleri ile ilgili ilgili açıklamalar su sistemi için de yapılmıştır. Figür 3 bu tanımlamaları özetlemektedir.

Mobus ve Kalton (2015) tarafından 12 adet genel prensip tanımlanmıştır. Bu prensipler şöyledir:

1. Prensip: Sistemsellik
2. Prensip: Sistemler Yapısal ve İşlevsel Hiyerarşilerle Organize Olmuş Süreçlerdir
3. Prensip: Sistemler Bileşenleri Arasındaki İlişkiler Ağından Oluşmaktadır ve İlişki Ağı Soyut Olarak Gösterilebilir
4. Prensip: Sistemler Çoklu Zaman ve Mekân Ölçeklerinde Dinamik Bir Yapıya Sahiptir
5. Prensip: Sistemler Farklı Tür ve Seviyelerde Karmaşık Bir Yapı Sergileyebilirler
6. Prensip: Sistemler Evrimleşir
7. Prensip: Sistemler Bilgiyi Şifreler, Alır ve Gönderir
8. Prensip: Sistemlerin Durağanlığa Ulaşması için Düzenleme Mekanizmaları Vardır
9. Prensip: Sistemler, Diğer Sistemlerin Modellerini İçerir
10. Prensip: Yeterince Karmaşık ve Uyarlanabilir Sistemler Kendi Modellerini de İçerir.
11. Prensip: Sistemler Anlaşılabilir
12. Prensip: Sistemler Geliştirilebilir

### **3.3.Ortaokul Derecesini Almış Öğrencilerin Sistemsel Okuryazarlık Hazırbulunuşluk Seviyeleri Nedir?**

Mevcut çalışma kapsamında ortaokulu bitirmiş dört 9. sınıf öğrencisinden veri toplanmıştır. Öbekler arası analiz sonuçları işlevsel, kültürel ve eleştirel sistem okuryazarlıkları altında raporlanmıştır.

#### **3.3.1. İşlevsel Sistem Okuryazarlık Hazırbulunuşluk Seviyeleri**

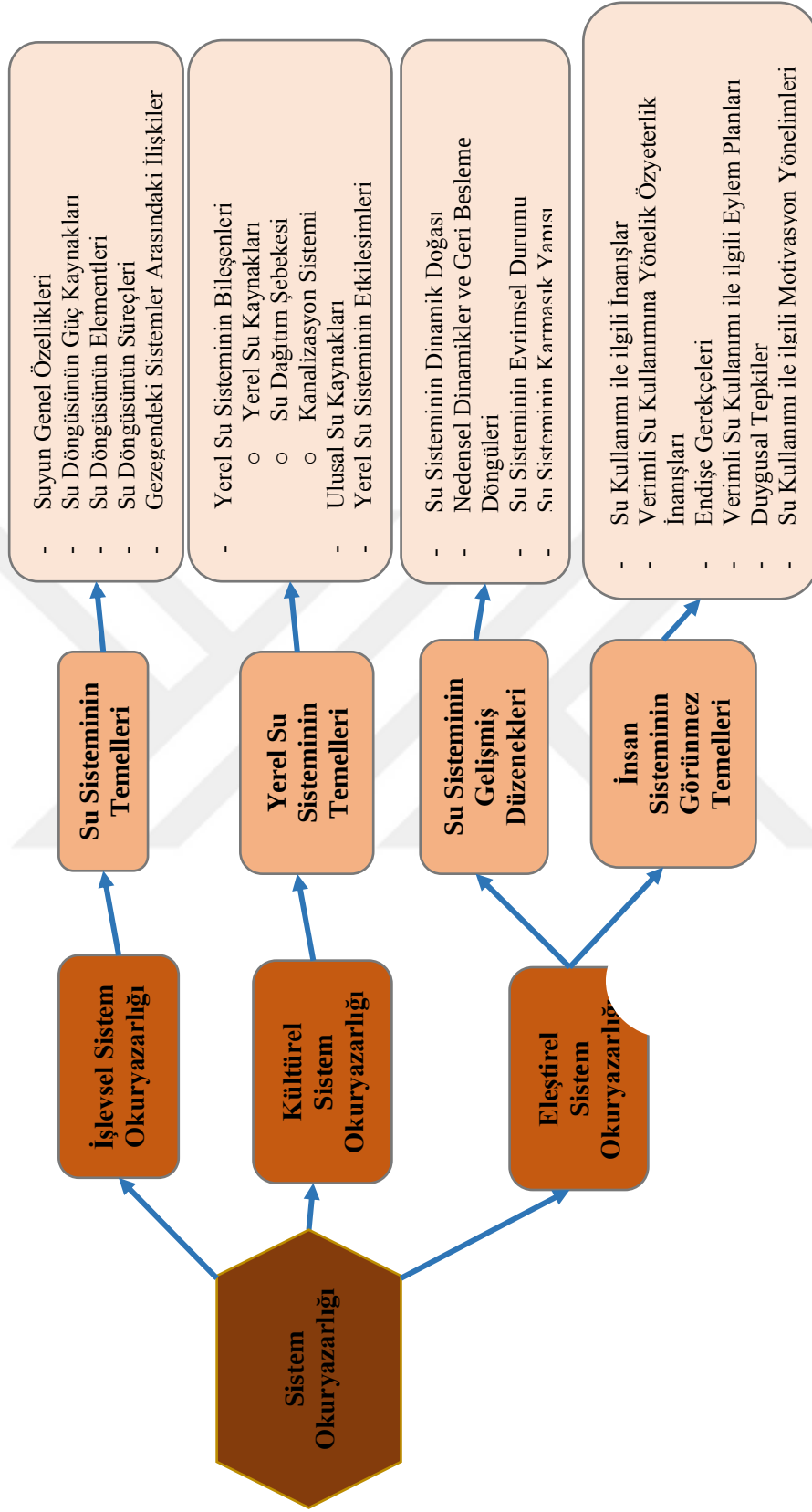
İşlevsel sistem okuryazarlık seviyeleri kavram testi, 1. çizim etkinliği ve yarı yapılandırılmış görüşme soruları ile ölçülmüştür. Analiz sonucunda elde edilen bulgular beş kategori altında toplanmıştır: (1) Suyun Genel Özellikleri; (2) Su Döngüsünün Güç Kaynakları; (3) Su Döngüsünün Elementleri; (4) Su Döngüsünün Süreçleri ve (5) Gezegendeki Sistemler Arasındaki İlişkiler. Suyun genel özellikleri kapsamında katılımcıların bildirimine dayalı bilgileri sürece dayalı bilgilerinden daha yüksektir. Suyun dünya üzerindeki toplam su miktarı bakımından öğrencilerin cevapları incelendiğinde, Ahmet ve Eren su miktarının neredeyse hiç değişmediğini belirtirken, Cansu ve Deniz'in alternatif kavramları teşhis edilmiştir. Suyun döngüsel doğası bakımından ise Deniz dışında bütün katılımcılar bu yapıdan bahsetmiştir. Fakat suyun döngüsel doğası ile ilgili sürece dayalı bilgileri oldukça kısıtlıdır. Su ve yaşayan organizmalardan bütün katılımcılar bahsetmiştir. Tüm katılımcıların bildirimine dayalı bilgi seviyeleri yüksekken sürece dayalı bilgi birikimlerinin yine kısıtlı olduğu belirlenmiştir. İlişkisel tepki kavramına ilişkin olarak Deniz hariç tüm katılımcıların birtakım bilgileri mevcuttur. Ahmet hem canlı ve cansız varlıkların tepkilerinden bahsederken Cansu canlı varlıklardan, Eren cansız varlıkların tepkilerinden bahsetmiştir.

# Sistem Okuryazarlığının Kavramsal Modeli



**Figür 3**

*Su Sistemi Bağlamındaki Sistem Okuryazarlığının Kavramsal Modeli*





Su sisteminin güç kaynaklarının hepsinden Cansu ve Deniz bahsederken Ahmet ve Eren rüzgârdan bir güç kaynağı olarak bahsetmemiştir. Bahsedilen bileşen sayısı en çok Ahmet ve Deniz'in cevaplarında gözlenirken hiçbir katılımcı kaya, aküfer, dolu ve tatlı sudan bahsetmemiştir. Bahsedilen süreç sayısı ise en çok Deniz'in cevaplarında mevcut iken sürece dayalı bilgi derecesinde doğru cevaplar Eren'in cevapları olmuştur. Gezegendeki sistemler arasındaki ilişkiler kategorisinde diğer kategorilerde olduğu gibi bildirim dayalı dayalı bilgi sürece dayalı bilgiden daha fazladır. En çok ilişki sayısı Ahmet'in cevaplarında mevcut iken Deniz'in sürece dayalı bilgi seviyesi Ahmet'ten yüksektir. Son olarak tüm katılımcıların bazı konularda alternatif kavramları ve tutarsız o sırada oluşturulmuş yanıtları mevcuttur. Katılımcıların etkileşim haritaları incelendiğinde ise Eren ve Deniz'de etkileşim sayıları diğerlerine göre daha yüksektir. En çok etkileşim içinde olan iki kategori ise bileşenler ve süreçler kategorileridir.

### *3.3.2. Kültürel Sistem Okuryazarlık Hazırbulunuşluk Seviyeleri*

Kültürel sistem okuryazarlık seviyeleri 2. çizim etkinliği ve yarı yapılandırılmış görüşme soruları ile ölçülmüştür. Analiz sonucunda elde edilen bulgular üç kategori altında toplanmıştır: (1) Yerel Su Sisteminin Bileşenleri; (2) Ulusal Su Kaynakları ve (3) Yerel, Ulusal ve Küresel Sistemler Arasındaki İlişkiler. Ayrıca kategoriler arasındaki etkileşim ağı üretilerek kültürel sistem okuryazarlık kavramındaki kategoriler arasındaki ilişkiler ortaya konmuştur. Kültürel sistem okuryazarlık konusundaki katılımcıların hazırbulunuşlukları bakılmış ve Cansu'nun birçok bilgisi bildirim dayalı olsa da diğer katılımcılar ile karşılaştırıldığında daha zengin bir yapıya sahiptir. Yerel su sisteminin bileşenleri ile ilgili analiz sonucunda elde edilen bulgular katılımcıların sürece dayalı bilgilerinin kısıtlı olduğunu ortaya koymuştur. Su dağıtım şebekesi ve kanalizasyon sistemi ile ilgili katılımcıların hepsinde bilgi eksiklikleri gözlenmiştir. Katılımcılar aynı zamanda tutarsız ve değişken yanıtlar vermişlerdir. Bütün katılımcılar bu sistemleri çok iyi bilmediklerini ifade etmişlerdir. Ulusal su kaynakları kategorisinde sadece Deniz bilgi sağlamıştır. Diğer katılımcılar yaşadıkları yerlerdeki su etkileşimleri ile ilgili yanıt vermişlerdir. Yerel, ulusal ve küresel

sistemlerin ilişkisi ile ilgili katılımcılar genel olarak nispeten daha fazla doğru cevapları vardır. Bu cevapların büyük kısmı bildirime dayalı bilgi içermektedir. Deniz bu kategoride diğer katılımcılara oranla daha sınırlı yanıtlar vermiştir. Etkileşim haritasında ise en çok etkileşimde olan kategori yerel, ulusal ve küresel sistemlerin ilişkisi olurken, yerel ve ulusal su kaynakları ve su dağıtım şebekesindeki süreçler en sınırlı bilgi alınan kategoriler olmuştur.

### *3.3.3. Eleştirel Sistem Okuryazarlık Hazırbulunuşluk Seviyeleri*

Eleştirel sistem okuryazarlık seviyeleri yarı yapılandırılmış görüşme soruları ile gerçek hikâyeye dayanan okuma etkinliği ile ölçülmüştür. Analiz sonucunda elde edilen bulgular iki tema ve 8 kategori altında toplanmıştır. Su sisteminin gelişmiş mekanizmaları ile ilgili olan tema dört kategori altında incelenmiştir. Suyun dinamik doğası kategorisinde bilinçsiz su kullanımının su sistemine etkisi üzerinden bilgi toplanmıştır. Bütün katılımcılar zaman ertelemesi ve dinamik etkileri kavramının farkında olsalar da olası sebepleri ve sonuçları ile ilgili sürece dayalı bilgileri kısıtlıdır. Nedensellik mekanizmaları ve geribesleme döngüleri kategorisinde her katılımcı pozitif geribesleme döngüsü konusunda dolaylı olarak bilgi akışı sağlasa da nedensellik mekanizmalarının büyük bir çoğunluğu açık uçlu döngüye sahip olup çoklu nedenselliğe dayanmaktadır. Sistemlerin evrimleşmesine dair ise Cansu ve Deniz su sisteminin gerilediğini düşünürken Ahmet farklı senaryolara göre değerlendirme yapmış, Eren ise su sisteminin kısa vadede sabit kalacağını savunmuştur. Sistemlerin karmaşık yapısı ise iklim değişikliği ve gizli su kullanımı üzerinden öğrencilere sorulmuştur. Elde edilen verilere göre, bütün katılımcılar sistemin çalışmasını sekteye uğratan olayları teşhis edebilmiş ancak Cansu ve Deniz bu konu hakkındaki sürece dayalı bilgilerini gösterememişlerdir. Karmaşıklık tabakaları incelendiğinde ise tüm katılımcılar çevre ve sosyal etkilerden bahsetmiştir. Gizli su kullanımı kısmında ise Eren ve Deniz bu terimi daha önce hiç duymadıklarını ifade etmişlerdir.

İnsan sisteminin görünmez elementleri ile ilgili de veri toplama süreci esnasında birtakım bilgiler elde etmek amaçlanmıştır. Öğrencilerin su kullanımı ile ilgili inanışları incelendiğinde, Cansu ve Deniz verimli su kullandıklarını iddia ederken Ahmet öyle bir motivasyon yöneliminin olmadığını belirtti. Eylem stratejileri içinse Ahmet hiçbir strateji raporlamamış ve bunu yapmanın anlamlı olmayacağını vurgulamış. Eren ve Cansu ise gizli su kullanımı kavramını duymamalarına rağmen kendileri suyu verimli kullandıklarını ifade etmişlerdir. Erkeklerde öz-yeterlik inanışı ile ilgili veri elde edilemese de kızların öz-yeterlik inanışı erkeklerden yüksek çıkmıştır. Duygusal tepkiler kategorisinde her katılımcının kendine özgü bir duygu kombinasyonları oluşmuştur. Motivasyon yönelimleri ile ilgili de Ahmet hariç tüm katılımcılar dışsal motivasyon yönelimlerini ortaya koymuşlardır. Ahmet ise bu konu hakkında amotive olduğunu belirtmiştir.

### **3.4.Su Sistemi Bağlamında Sistem Okuryazarlığını Etkileyen olası Faktörler**

Çalışma kapsamında birkaç tane değişkenin sistem okuryazarlığı bileşenleri ile etkileşime girdiği verisine ulaşılmıştır. Bu değişkenler cinsiyet, günlük hayat tecrübeleri, bilişsel farklılıklar, sosyoekonomik statü göstergeleri, yaşadıkları yer ve aile ile etkileşim olarak gözlenmiştir.

Özet olarak, deneysel araştırma analizleri sonucunda öğrencilerin eleştirel sistem okuryazarlık seviyelerinin işlevsel veya kültürel okuryazarlık seviyesindeki eksiklikler sebebiyle yetersiz olduğu gözlenmiştir. Eleştirel sistem okuryazarlıkları hem işlevsel ve kültürel okuryazarlıkları ile hem de öğrencilerin alternatif kavramları ve değişken yanlış cevapları sebebiyle etkileşmektedir. Ek olarak, bazı olası faktörlerin de bireylerin sistem okuryazarlıkları ile ilişkili olduğu gözlemlenmiştir.

## **4. Tartışma ve Sonuç**

Eleştirel sistem okuryazarlıkları hem işlevsel ve kültürel okuryazarlıkları ile hem de öğrencilerin alternatif kavramları ve değişken yanlış cevapları sebebiyle etkileşmektedir. Bu etkileşimler, eleştirel okuryazarlığın gelişmesinde bir engel olarak

nitelendirilebilir. Çalışmanın bulguları fen eğitimi ve sürdürülebilir kalkınma için eğitim programlarına sistem bilimlerini entegre etmek için sistem okuryazarlığı kavramının önemini ortaya çıkarmıştır. Sonuç olarak, eğitimcilere ve program geliştirme uzmanlarına, sistemsel okuryazarlık kapsamında bir entegrasyon öncesinde, bireylerin hazırbulunuşluk seviyelerini belirlemeleri önerilmektedir.

Sistem okuryazarlığı ile ilgili alan yazını 2000li yılların başından beri farklı disiplinlerde gelişmeye devam etmektedir. Ulaşılabilir alan yazınındaki tanımlar ve kavramsal çerçeveleri incelemiş ve fen eğitimi alanında çalışan bir sosyal bilimci gözünden alternatif bir tanım ve çerçeve ortaya atmış olsam da bu alanın hala çok yeni olduğunu ve gelişmeye çok açık olduğunu söyleyebilirim. Öte yandan, eleştirel sistem okuryazarlığı kavramının içerisinde başka muhtemel yapıların olabileceğinin farkındayım. Bunun da ötesinde, bu çalışmada sunulan bazı yapıların farklı bağlamlarda farklı şekilde katkıda bulunabileceğini düşünüyorum. Bu sebeple, sonraki sistem okuryazarlığı çalışmaları yapacak olan araştırmacıların bu olasılıkları dikkate almasını öneriyorum.

İşlevsel ve kültürel sistem okuryazarlıkları önemli bileşenler olmasına rağmen tek başına yeterli olmamaktadırlar (Stables, 1998). Öte yandan, eleştirel sistem okuryazarlığı hem işlevsel hem de kültürel sistem okuryazarlıklarından beslendiği için önemli bir noktada yer almaktadır. Çalışmanın bulguları incelendiğinde, eleştirel sistem okuryazarlığı içerisindeki ileri düzeydeki sistem mekanizmaları açısından mevcut çalışmada katılımcılar arasında sınırlı olduğu sonucuna varılmıştır. İleri düzey sistem mekanizmaları hem işlevsel hem de kültürel okuryazarlıklarla etkileşime girerken, aynı zamanda katılımcıların alternatif kavramları ve tutarsız açıklamaları tarafından gelişmemektedir. Bütün bunlara ek olarak, Ahmet'in diğer katılımcılara oranla daha yeterli işlevsel ve kültürel sistem okuryazarlık seviyesi olmasına rağmen, amotive oluşu ve ilgisiz davrandığını ifade etmesinden yola çıkılarak Ahmet'in eleştirel okuryazarlığını insan sisteminin görünmez elementleri teması kapsamında sınırlı hale getirmekte olduğuna kanaat getirilmektedir. Bu noktada, bireylerin eleştirel sistem okuryazarlıklarını geliştirmek için işlevsel ve kültürel okuryazarlıklarını

geliştirmenin yanı sıra motivasyon yönelimlerine yönelik birtakım adımların atılmasının önemli olduğu sonucu çıkmaktadır.

İleriki çalışmalar için sistem okuryazarlığının birbirini tamamlayan üç bileşeni olan işlevsel, kültürel ve eleştirel sistem okuryazarlıklarını dahil etmek öneri olarak sunulabilir. Diğer taraftan, bileşenlerin altındaki temalar ve kategoriler seçilen sistemin bağlamına ve veri toplanacak popülasyonun karakteristiğine göre değişiklikler gösterebilir.

Bilgi seviyesinin tiplerine ek olarak, alternatif kavramlar ve görüşme anında söylenen tutarsız açıklamalar (in-situ answers) da bireylerin sistem okuryazarlıkları konusunda doğru bilgi edinmede önemli bir nokta olabilir çünkü bu yapılar bireylerin işlevsel, kültüre ve eleştirel sistem okuryazarlıklarının geliştirilmesi önünde bir engel olarak karşımıza çıkmaktadır. Bütün bunları tespit etmek için, çoklu veri toplama araçları kullanmak önemli bir noktadır. Örneğin, bu çalışmada sadece dört aşamalı kavram testi kullanılsa idi bazı alternatif kavramlar ve tutarsız açıklamaları tespit etmek mümkün olmayacaktı. Kullanılan çizim etkinlikleri ve yarı yapılandırılmış görüşme soruları ile beraber mevcut çalışmada listelenen bulgulara ulaşılmıştır.

Katılımcıların sınırlı düzeyde eleştirel sistem okuryazarlığına sahip olmaları eleştirel veya kültürel sistem okuryazarlıklarındaki sınırlıktan kaynaklandığı sonucuna varılmıştır ve benzer bulgular alan yazınında bulunmaktadır (Stables, 1998). Bunların dışında, spekülatif olsa da katılımcıların eleştirel sistem okuryazarlıklarındaki sınırlılıklarının ek sebepleri olabilir. Bu ek sebepler (1) katılımcıların alternatif kavramlarının onların potansiyellerini kısıtlaması; (2) ulusal fen eğitimi müfredatının öğrencilerin sistem okuryazarlıklarını geliştirmek için uygun fırsatları sunamaması veya (3) katılımcıların hem işlevsel hem de kültürel sistem okuryazarlıklarının aynı anda aynı düzeyde gelişmiş olmaması olarak listelenebilir.

Bu çalışmada bazı değişkenlerin sistem okuryazarlığı ile etkileştiği gözlemlenmiştir. Bunların arasında müfredat dışı katılan aktiviteler göze çarpmaktadır. Bu etkinliklerde anlatılanlar veya uygulanan öğrenciler tarafından kolaylıkla hatırlanmaktadır. Ancak,

davranışa yansıma konusunda etkili olmadıkları görülmektedir. Bu noktada, örgün eğitimin sistem okuryazarlığını desteklemesi ve geliştirmesi anlamındaki potansiyelinin önemi bir kez daha ortaya çıkmaktadır. Gerekli düzenlemeler yapıldığı takdirde sistem okuryazarlığını destekleyen bir örgün eğitim bireylerin sistem okuryazarı olması hususunda önemli katkılar sağlayacaktır.



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