# ASSESSING PRE-SERVICE SCIENCE TEACHERS' SYSTEMS THINKING SKILLS USING REAL LIFE SCENARIOS

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Approval of the Graduate School of Social Sciences

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**ABSTRACT**

ASSESSING PRE-SERVICE SCIENCE TEACHERS' SYSTEMS THINKING SKILLS USING REAL LIFE SCENARIOS

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The main purpose of this study is to investigate pre-service science teachers' systems thinking skills with using a real-life scenario as an assessment tool. The nine systems thinking skills defined in this research were discussed in terms of sustainable development. Participants were expected to comprehend integrated nature of environmental, economic and social aspects of this concept in a systemic perspective. Therefore, the real-life scenario used for assessment was selected related with sustainable development. Data collection procedure was conducted with six senior pre-service teachers from the elementary science education department of a public university in Turkey. Their interpretations on the real-life scenario were acquired through semi-structured interviews. Data obtained from each participant was discussed separately in this multiple case study. Interviews were analyzed by using the rubric developed for systems thinking skills discussed in the present research.

This study intended to provide an insight for assessment of systems thinking skills and to inspire educators interested in sustainable development. Findings showed that participants' systems thinking levels were changing in a nonhierarchical order and connected with the personal experiences. Additionally, it was observed that real life scenarios provide an in-depth information to participants for discussion. Moreover, it was noticed that there is a weak conception about sustainable development among the participants. While commenting on the scenario, environmental aspect was emphasized more than the other two aspects of sustainable development. In general, this study revealed that real-life scenarios are effective tools in assessment of systems thinking skills.

**Keywords:** Systems Thinking, Real-life Scenarios, Sustainable Development, Pre-Service Science Teachers

# ÖZ

FEN BİLİMLERİ ÖĞRETMEN ADAYLARININ SİSTEMSEL DÜŞÜNME BECERİLERİNİN GERÇEK YAŞAM ÖYKÜLERİ KULLANILARAK DEĞERLENDİRİLMESİ

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Bu çalışmanın amacı fen bilimleri öğretmen adaylarının sistemsel düşünme becerilerinin değerlendirilmesinde gerçek yaşam öykülerinin kullanımını incelemektir. Bu çalışmada literatürde tanımlanan dokuz sistemsel düşünme becerisi sürdürülebilir kalkınma bağlamında ele alınmıştır. Katılımcılardan sürdürülebilir kalkınma kavramını oluşturan çevre, ekonomi ve toplum boyutlarının bütünleşik yapısını sistemsel bir bakış açısıyla açıklamaları beklenmektedir. Bu nedenle, değerlendirme amacıyla kullanılan gerçek öykünün sürdürülebilir kalkınmayla ilişkili olmasına dikkat edilmiştir. Veri toplama süreci bir devlet üniversitesindeki altı son sınıf fen bilimleri öğretmen adayı ile yürütülmüştür. Katılımcıların gerçek yaşam öyküsü hakkındaki yorumları yarı yapılandırılmış görüşmelerle elde edilmiştir.

Bu çoklu durum çalışmasında her katılımcıdan elde edilen veriler ayrı başlıklarda incelenmiştir. Görüşmeler ile elde edilen veriler, bu çalışmada ele alınan sistemsel düşünme becerileri için geliştirilen bir rubrik kullanılarak analiz edilmiştir.

Bu araştırma, sistemsel düşünme becerilerinin değerlendirilmesi ile ilgili bir fikir oluşturmayı ve sürdürülebilir kalkınma ile ilgilenen eğitimcilere ilham vermeyi hedeflemektedir. Bulgular, katılımcıların sistemsel düşünme becerilerinin hiyerarşik olmayan bir düzende değiştiği ve kişisel deneyimlerine bağlı olarak değiştiği gözlemlenmiştir. Dahası, katılımcıların sürdürülebilir kalkınma hakkında zayıf bir kavrayışa sahip oldukları gözlemlenmiştir. Gerçek yaşam öyküsü üzerine yapılan çıkarımlarda sürdürülebilir kalkınmanın çevresel boyutu diğer iki boyutundan daha fazla vurgulanmıştır. Sonuç olarak, bu araştırma gerçek yaşam öykülerinin ele aldıkları konu hakkında katılımcılara geniş bir bilgi sunduğunu ve sistemsel düşünme becerilerini ölçmede etkili araçlar olduklarını göstermiştir.

**Anahtar Kelimeler:** Sistemsel Düşünme, Gerçek Yaşam Öyküsü, Sürdürülebilir Kalkınma, Fen Bilimleri Öğretmen Adayları

To all children in the world

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| | |
|---|---|
| STS | Systems Thinking Skills |
| ESD | Education for Sustainable Development |
| NRC | National Research Council |
| NGSS | Next Generation Science Standards |
| UNECE | United Nations Economic Commission for Europe |
| UNESCO | United Nations Educational Scientific and Cultural Organization |
| UN | United Nations |
| UNCED | United Nations Conference on Environment and Development |

# CHAPTER 1

# INTRODUCTION

## 1.1.Background Information

Modern world presents important complex systemic structures for everyday life in various contexts such as ecology, economy or society. The sophisticated structure of these systems provides development of new perspectives and methodologies for every part of the society that is affected by the dilemmas of the 21st century. (Jacobson & Wilensky, 2006; Lesh, 2006). These complex systems include many integrated sublevels. Building a network of relationships among these sublevels is required for comprehension of the complex systems. However, the connections between these sublevels are not necessarily apparent. This character of the complex system makes perception of them problematic (Hmelo-Silver & Pfeffer, 2004). The complex systems are characterized in terms of their patterns, cyclic nature, integrated structure; and interactions among the elements of the system. In addition, components of the system can also have a systemic structure inside themselves (Goldstone & Wilensky, 2008; Herbert, 2006). Even though interpretation of complex systems might be struggling, their comprehensive nature provides researchers to study complex systems in different fields of research ranging from social sciences to earth sciences including subjects like business, sociology, environment, engineering, biology, chemistry, physics or medicine (Hmelo-Silver & Azevedo, 2006; Jacobson & Wilensky, 2006).

In the field of education, study of complex systems provides a shift in understanding scientific phenomena by developing unique perspectives and frameworks which connect different scientific disciplines such as physics, chemistry, biology and social sciences. (Jacobson & Wilensky, 2006).

In science education complex systems are common, mainly because scientific knowledge forms with different constituents from different scientific practices. Instead of separated set of facts, science works in a collaborative way. This brings the necessity to gather knowledge from different sources in order to establish new information. On the other hand, textbooks present information as fragmented set of knowledge are not successful to develop a sense of complex systems in learners' minds (Liu & Hmelo- Silver, 2009).

It was asserted that a complex systemic comprehension can only be constructed when there is a network of interrelated components from different levels of the system. Nevertheless, mostly students are facing with explanations of complex systems as linear structures without noting the connections (Hmelo, Holton, & Kolodner, 2000; Hmelo- Silver & Pfeffer, 2004).

Systems thinking produces a path for understanding such complex systems as connected body of elements in a cyclic and integrated nature (Hung, 2008). Building systems thinking skills (STSs) enables to deal with large amount of knowledge and improves decision making abilities of students (Raved & Yarden, 2014). Wylie, Sheehy, McGuinness and Orchard (1998) pointed out several descriptions of systems thinking. In the literature, systems thinking skill was defined as knowing of the fact that world is composed of interrelated and interacted components which forms a deep unifying structure. National Research Council (NRC) also reported systems thinking as one of the 21$^{st}$ century skills in education. Systems thinking was defined as the ability to comprehend the "big picture" of a system, including the analysis, the evaluation and reasoning about the elements and operation of these elements in

the system. It is a critical thinking skill for both scientists and citizens that help to discover the problems related to science & environment and develop answers to them (NRC, 2010).

In general, systems thinking was classified as a high level cognitive ability (Hung, 2008; Lee, 2015; Zoller, 2011). As a higher order thinking skill, systems thinking helps one to conceive different parts, the interactions between these parts, the entire process ongoing as a result of these interactions and the whole system. It is a cognitive skill to broaden the ordinary perception of the phenomena and facilitating the comprehension of complicated interactions, complex systems and the complications occurring inside these systems (Zoller & Nahum, 2012). If there is a successful understanding of the relationships and the cycle within the system, one will be able to provide possible treatments with their outcomes to the problems in the system (Wylie et. al., 1998).

Ben-Zvi Assaraf and Orion (2005), proposed a model for systems thinking called Systems Thinking Hierarchy (STH) Model. The authors defined eight systems thinking skills (STS) for students in the context of earth systems. Systems thinking skills were ordered according to their development sequence in students' minds. These eight systems thinking skills and levels are presented in Table 1.1.

*Table 1.1: Systems Thinking Hierarchical Model (Ben-Zvi Assaraf & Orion, 2005, p.523)*

| System Thinking Skills | Levels |
|---|---|
| 1- The ability to identify the components of a system and processes within the system. | Analysis of system components |
| 2- The ability to identify simple relationships between or among the system's components.<br>3- The ability to identify dynamic relationships within the system.<br>4- The ability to organize the systems' components, processes, and their interactions, within a framework of relationships.<br>5- The ability to identify cycles of matter and energy within the system—the cyclic nature of systems. | Synthesis of system components |
| 6- The ability to recognize hidden dimensions of the system—to understand natural phenomena through patterns and interrelationships not seen on the surface.<br>7- The ability to make generalizations—to solve problems based on understanding systems' mechanisms.<br>8- The ability to think temporally: retrospection and prediction. Understanding that some of the presented interaction within the system took place in the past, while future events may be a result of present interactions. | Implementation |

In the context of science education, systems thinking was studied in various subjects including: earth systems (i.e., water cycle, carbon cycle, rock cycle) (Ben-Zvi Assaraf & Orion, 2005; Gudovitch & Orion, 2001; Kali, Orion & Eylon, 2003; Scherer, Holder, & Herbert, 2017; Sibley et al., 2007); biological systems, such as human body systems, pollination, ecosystem (Eilam, 2012; Evagorou, Korfiatis, Nicolaou, & Constantinou, 2009; Golick, Dauer, Lynch & Ingram, 2017; Liu & Hmelo- Silver, 2009; Hmelo- Silver, Marathe, & Liu, 2011; Raved & Yarden, 2014; Riess & Mischo, 2010); Verhoeff, Waarlo & Boersma, 2008) and sustainability (Nguyen &. Bosch, 2013)

## 1.2.Systems Thinking and Sustainable Development

Complex problems of 21st century have also been addressed in the sustainable development literature. Orr (2004), drew attention to the valuable concepts that are threatened for future like climate, natural resources, biodiversity. He noted that none of these challenges that the world has faced today were resulted from the actions of the uneducated people and he declared a need of change in education.

In order to discuss sustainable development in the context of education, it is worthwhile to comprehend the meaning of sustainable development. The definition of sustainable development that was presented in the Brutland Report is:

"Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987, p. 43).

This general definition implies development in different fields. Denoting "economic development, social development and environmental protection", as three pillars of sustainable development made it possible to form a concrete definition of this subject. It is important to note that environment, economy and society propose an interdependent structure to achieve sustainable development (United Nations, 2002). In 2005, UNESCO, gave detailed explanations for these three concepts:

> "Society: an understanding of social institutions and their role in change and development, as well as the democratic and participatory systems which give opportunity for the expression of opinion, the selection of governments, the forging of consensus and the resolution of differences.
>
> Environment: an awareness of the resources and fragility of the physical environment and the effects on it of human activity and decisions, with a commitment to factoring environmental concerns into social and economic policy development.

> Economy: a sensitivity to the limits and potential of economic growth and their impact on society and on the environment, with a commitment to assess personal and societal levels of consumption out of concern for the environment and for social justice." (UNESCO, 2005, p. 5)

In 1992, United Nations (UN) published Agenda 21. In this document, education was remarked as one of the key components of sustainable development (UNCED, 1992). After this publication, all UN declarations on sustainable development pointed out that education is the key part of the change (UNECE, 2004). Thereby, "Education for Sustainable Development" (ESD), has emerged as a critical issue and became an educational strategy to increase the awareness in environmental problems and sustainability. United Nations Economic Commission for Europe (UNECE), declared the "UNECE Regional Strategy on ESD" in 2005 "High-Level Meeting of Environment and Education Ministries" with delegates from 40 countries, including Turkey. The UNECE strategy document asserts that Education for Sustainable Development increases the ability of countries, organizations and citizens to think critically and make decisions regarding sustainable development. The strategy suggests that ESD includes key elements for sustainable development into the process of teaching and learning. Nevertheless, those key issues extend from environmental protection to biological diversity and economy to production. It is important to note that this strategy also involves motivating learners to alter their behavior and act in the issues in sustainable development with developing critical thinking skills, decision making abilities and an insight of future (UNECE, 2005).

Accordingly, the integrated nature of sustainable development requires a complex thinking scheme to complete understanding of the concept. Connecting the environmental, economic and social subsystems of the sustainable development arises the need of systems thinking. Systems thinking has a potential to shape one's mind to find out the countless connections among these three concepts (Wheeler, 2000). The connection between sustainable development and systems thinking offers an implementation in

Education for Sustainable Development. Acquiring an insight on complex systems of environment, economy and society; recognizing the relationships between these systems and the constraints of change of these systems; and the general image of these three systems offers a solution for ESD to reach its goal (Byrne, 2000).

Individuals' ability to perceive dynamic and systemic character of complex global problems is highly related with their thinking abilities and requires developing a deep insight on complex problems from both local and global contexts. So, systems thinking offers a way for improving the perception of the entire world as a system (Wylie et al. 1998). Additionally, it is important to raise students as citizens who are able to understand the reason behind complex global problems and produce solutions for a sustainable future. In order to reach this goal, students need to develop a perception that enables them to find out inner connections between the components of the natural and human-made systems around them and create a whole view (Ben-Zvi Assaraf, 2004).

The research related to ESD and systems thinking has been dealing with variety of samples; such as, students (Batzri, Ben-Zvi Assaraf, Cohen & Orion, 2015; Ben-Zvi Assaraf & Orion, 2005; Ben-Zvi Assaraf & Orion, 2010; Eilam, 2012; Evagorou et al., 2009; Shepardson, Roychoudhury, Hirsch, Niyogi, Top, 2014) and teachers (Ateskan & Lane, 2017; Karaarslan, 2016; Schuler, Fanta, Rosenkraenzer & Riess, 2017; Lee, 2015). Because systems thinking was classified as a higher order thinking skill the teachers' role in the implementation of systems thinking into the ESD is highly influential. Besides, for teachers, "the ability to think about systems" is one of the skills to be effective ESD educators (McKeown, 2002). It is stated that the science educators who perceive science from a more detailed and surrounding point of view and consider the social and scientific values together are considerably more qualified in ESD (Hart, 2007).

The role of teacher education is vital in this context. It is found that ESD for teachers creates a vision on both environmental and social challenges of the 21st century (Nolet, 2009). Even though student teachers are attending courses on sustainability to construct a basis for perceiving ESD, their systems thinking skills are still shows a weak progression (Foley, Archambault, & Warren, 2015). The undergraduate courses in the education faculties need improvements to reform the linear curriculum and concentrate on process and interactions (Egger, Kastens, & Turrin, 2017). For example, an attempt to improve systems thinking skills of science teachers, Karaarslan (2016) designed an outdoor course and presented twelve systems thinking skills in the context of sustainable development course (see Table 1.2).

*Table 1.2: Systems Thinking Skills (STSs) (Karaarslan, 2016, p. 10)*

| | |
|---|---|
| STS 1 | Identifying aspects of sustainability |
| STS 2 | Seeing nature as a System |
| STS 3 | Identifying components of a system |
| STS 4 | Analyzing interconnections among the aspects of sustainability |
| STS 5 | Recognizing hidden dimensions |
| STS 6 | Recognizing own responsibility in the system |
| STS 7 | Considering the relationship among past, present and future |
| STS 8 | Recognizing cycling nature of the system |
| STS 9 | Developing empathy with other people |
| STS 10 | Developing empathy with non-human beings |
| STS 11 | Developing a sense of place |
| STS 12 | Adapting systems thinking perspective to one's personal life |

Framework for the currently presented thesis was adopted systems thinking skills from both Ben-Zvi Assaraf (2005)'s STH model and Karaarslan (2016)'s STSs.

There are different assessment techniques for systems thinking used in previous research. Concept maps, interviews, cyclic thinking questionnaire, drawings, word associations, repertory grids, ecology system inventory essays, case study analysis, rubrics and systems thinking scale (Ateskan & Lane, 2017; Ben-Zvi Assaraf & Orion, 2005; Brandstadter, Harms, Grossschedl, 2012; Karaarslan, 2016; Tripto, Ben-Zvi Assaraf, Snapir & Amit, 2016) are some of them.

### 1.3.Using Real Life Scenarios in Assessing Systems Thinking Skills

One of the assessment tools for assessing systems thinking skills is real life scenario analysis as used by Karaarslan (2016). The author reported the usefulness of the real-life scenario as a data collection tool for systems thinking. Moreover, Remington- Doucette, Hiller Connell, Armstong & Musgrove (2013) also used real-life scenarios in the context of analyzing systems thinking and emphasized the importance of the tool to provide an insight when real experiences are not attainable.

Even though using real-life scenarios is not widespread as an assessment tool for assessing systems thinking skills, utilizing real-life scenarios in the context of sustainable development is quite a common practice in the field of education for sustainable development. Erdogan and Tuncer (2009) for example, asserted that real-life scenarios were one of the most functional tools to develop connection with the personal experiences and the scenario. They observed that real-life scenarios made participants to recognize the effects of the changes in the environment. Additionally, Tilbury (2011), reported use of real-life scenarios as an ESD pedagogy which can be used to stimulate the conversation and initiate a critical analysis of the subject. Moreover, real-life scenarios also appeared in Tuncay's (2010) study in the context of environmental education and moral reasoning. The real-life scenarios were used to measure the moral reasoning patterns of pre-service science teachers on environmental problems.

The author asserted that this tool might help to investigate the logic, comprehension, stance and awareness of teachers in the context of environment.

In accordance with the above summarized literature, real-life scenarios are used as a tool in this thesis in order to assess pre-service science teachers' perception of sustainable development and systems thinking skills.

### 1.4.Purpose of the Study

This thesis aims to reveal the systems thinking levels of pre-service science teachers and their conceptions of sustainable development with using real-life scenarios as an assessment tool. The research questions that will be investigated in this study are:

(1) What are the systems thinking levels of pre-service science teachers in terms of sustainable development?

(2) What are pre-service science teachers' conceptions of sustainable development?

It was indicated that in teacher education there is a need for more concentrated effort in order to make science teachers more competent in sustainability and environment (Esa, 2010). Therefore, in this study it is hypothesized that pre-service science teachers' level of systems thinking skills shape their perception of sustainable development.

### 1.5.Significance of the Study

The world is developing in a more and more complex and interdependent system. On the other hand, education in schools still presenting the information as fragmented and separate forms with making students fail to recognize systemic conceptions. Systems thinking is a significant cognitive tool to

analyze major issues in their environment. However, even among people with higher educational degrees systems thinking abilities can show low ranking (Booth Sweeney & Sterman, 2007).

Accordingly, a need in education about shifting the thinking habits is prominent. Systems thinking addressed as a valuable tool in education. Although it was classified as a higher order thinking skill it also provides a support for changing "teaching-to-know" conception to "learning-to-think" which promotes more critical perspective (Zoller, 2011). In addition, comprehension of science in all disciplines requires perception of systems in order to gain critical reasoning (Lee, 2015). National Research Council (1996), pointed out the importance of "systems" with referring to the systematic concepts that involves in science course with addressing that the nature around us is works as a complex system. Learning the units with systemic understanding helps students to perceive the basic laws of nature, theories and models with a detailed perspective. In addition to this, the Next Generation Science Standards (NGSS) presents systems thinking as one of the crosscutting concepts, as a tool for understanding main ideas in an advanced vision and construct a base knowledge for scientific dimension of the world (Achieve, Inc., 2013).

On the other hand, it is stated that while there are more studies issues systems thinking abilities for students, there is not enough research understanding this skill in teachers (Karaarslan, 2016). Therefore, the first significance of this research is to provide an insight for understanding systems thinking skills of pre-service science teachers.

Second significance of this study is combining ESD, systems thinking, teacher education and sustainable development. This research can be used in understanding the effect of systems thinking ability on conceptualizing sustainable development. It is important to highlight how teachers develop

their perceptions for ESD in their undergraduate education. Among the undergraduate courses of science education, sustainable development is not a widely studied topic as other main science topics such as physics, chemistry and biology. Sustainable development concept is not issued in these courses, even if it is related to the subject area. How teachers improve their understanding about sustainable development in education is mostly related with their personal experiences and interests. It is found that in-service teachers have insufficient understanding of sustainable development. There is a lack of knowledge about "sustainable development" and "education for sustainable development" that limits in-service teachers on that topic (Sagdic, 2013).

ESD is also a significant concept in education in Turkey. As a part of UNECE commission, Turkey adopted the ESD policy in its national curriculum. With an attempt to develop with an attempt to develop a curriculum that supports education for sustainable development, the topics of "universe, living organisms, and life, biodiversity, matter, energy and the relationship between human and environment" were added to the science curriculum (Erdogan, Marcinkowski, & Ok 2009). While science curriculum issues "sustainable development" there were still criticisms about the broadness of the curriculum on this topic. Tanriverdi (2009), results that environment concept in the elementary education program was limited with natural environment, and environmental protection, but social and cultural environment concepts were ignored. In the same study, it is also noted that the quality and the quantity of the objectives were not enough for a higher-level understanding.

In the "Sustainable Development Report: Claiming the Future", published by Ministry of Development in 2012; sustainable development and education were discussed. In this report, it is stated that sustainable development and education are closely related. Environmental awareness and sustainability concepts included in the national curriculum in order to enable future generations can adopt an inquiry of sustainable development into their lives. (Ministry of

Development, 2012). Accordingly, the national curriculum published in 2013 listed sustainable development as one of the components of Science - Technology- Environment- Society (STES) learning domain. In this curriculum, sustainable development defined as developing consciousness about using natural resources efficiently to meet the needs of the future generations and consider the individual, societal, economic benefits (Ministry of National Education, 2013). In 2017, Ministry of National Education published the new Turkish elementary science curriculum. Although, STSE learning domain is excluded from the current science curriculum, sustainable development is still present among the general aims. In this section, sustainable development defined by pointing out the interaction between people, environment and society and the awareness of the relation inside the society, natural resources and economy. Also, sustainable development is placed as one of the subjects of the 8$^{th}$ grade. (Ministry of National Education, 2017).

The third significance of this thesis is the adopted assessment technique. A framework for analysis of systems thinking skills of pre-service science teachers is provided with using systems thinking skills identified in literature and real-life scenario.

Briefly, this thesis aims to provide an analysis on systems thinking skills of pre-service science teachers in the context of ESD by designing a real-life scenario as an assessment technique. This study may offer a perspective for improvement of undergraduate courses in the education faculties. With this respect the audience of this study is academicians and researchers who are interested in systems thinking, education for sustainable development and science teacher education.

## 1.6.Definition of the Terms

**System:** A system is a structure of different elements which operate in a unified manner. Thus, changes in a single part of the system cause changes in the whole system. This integrated and cyclic body functions in a specified design and aim. (Ben-Zvi Assaraf & Orion, 2005)

**Systems Thinking:** "The ability to understand how an entire system works; how an action, change, or malfunction in one part of the system affects the rest of the system; adopting a "big picture" perspective on work. It includes judgment and decision making, systems analysis, and systems evaluation as well as abstract reasoning about how the different elements of a work process interact" (NRC, 2010, p. 3).

**Sustainable Development:** "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987, p. 43)

**Education for Sustainable Development: "**ESD is fundamentally about values, with respect at the centre: respect for others, including those of present and future generations, for difference and diversity, for the environment, for the resources of the planet we inhabit. Education enables us to understand ourselves and others and our links with the wider natural and social environment, and this understanding serves as a durable basis for building respect. Along with a sense of justice, responsibility, exploration and dialogue, ESD aims to move us to adopting behaviors and practices that enable all to live a full life without being deprived of basics" (UNESCO, 2005, p. 5).

# CHAPTER 2

# LITERATURE REVIEW

## 2.1.Systems Thinking and Sustainable Development

The first and most commonly used definition of sustainable development was published in the Brutland Report (United Nations General Assembly, 1987). However, since 1987, this definition changed and improved into an intersection of environment, society, and economy. In other words, sustainable development can be perceived as it is balanced in those three concepts to maintain the life quality. Agenda 21 discussed ESD with emphasizing the role of education in terms of raising awareness in people and developing a conscious society. According to that report, education is a critical component in enhancing the ability of people to relate environment and development concepts (UNCED, 1992).

ESD plays an important role for developing future generations with an understanding of sustainable development. Nevertheless, discussing only environmental problems in ESD application creates a limited perspective. In general, ESD is designed for a continuous learning process for learners to give decisions in the direction of well-being, and in favor of sustainable development with systemic and creative thinking skills (UNESCO, 2006).

When the related literature is investigated, it is noticed that there is a gap in teacher education in terms of "sustainable development" topic. Studies reported that pre-service teachers have insufficient understanding on sustainability and environmental issues that should be improved during undergraduate education.

In this regard, there is a need for designing an education program concerning education for sustainability (Mills & Tomas, 2013).

About how teacher training should be implemented in ESD, it is stated that "content knowledge, system thinking, emotions, values and ethics, and action are five key components for teachers involved in ESD (Sleurs, 2008). A study implemented with Turkish elementary science teachers, examining the environmental awareness of pre-service science teachers, revealed that taking environment related courses in the graduate level helps to improve beliefs and attitude on environmental issues (Tuncer, Tekkaya & Sungur, 2006).

A content analysis study was presented systems thinking as a part of environmental education and sustainability (Cloud 2005). The author addressed that systems thinking is a part of sustainability and could cover the topics like "economy, participate democracy, justice & equity and health of the ecosystems" (p.225) that sustainable development comprises. The study claimed that all the topics in sustainability presents a system. Therefore, systems thinking should be used in education for sustainability.

In the study conducted by Tejeda and Ferreira (2014), systems thinking was discussed in terms of sustainability in the field of wind energy. The authors suggested that systems thinking develops a way of understanding for implementing the three major components of sustainability, which are "environment, society and economy". They developed a systemic model to present wind energy and the relationship between the components. They concluded that this systematic model helps to understand the sustainability dimensions in an energy system.

Uri Zoller (2011), studied systems thinking as an instrument for meeting the needs of sustainability by referring to STES concept. He argued that the increasing effort for education for sustainability requires a paradigm shift mainly in the context of STESEP (science- technology- environment- society-

economy- policy), in all parts of education. Systems thinking approach provides a new conceptualization for this shift and he stated a new practice for using higher-order cognitive skills (HOCS) promoting "learning to think" instead of using lower-order cognitive skills (LOCS) promoting "teaching to know". As a higher order thinking skill, systems thinking involved in this study for implement HOCS in science classroom. He resulted that STES conceptualization with using HOCS for sustainability needs more practice but is achievable.

Another article discussed the exploration of sustainable development in the professional needs and presents a workshop program for sustainable development in professional trainings (Martin, 2008). The author proposed sustainable development in a context of systems thinking practice in this workshop. He concluded that such a workshop might help to increase organizational decision-making abilities and systemic relations within the sustainable development agenda.

### 2.2.Systems Thinking in Education

Researchers in education proposes systems thinking as a solution to the complex problems of the 21st century. Therefore, this thinking skill was studied from different aspects.

Sleurs (2008) proposed that systems thinking supports finding interrelations and patterns. Consequently, he discussed the complexity of the current global problems and suggested that systemic thinking is necessary to avoid future complications. He argued that developing systems thinking ability in teachers helps to provide solutions to the difficulties in education for sustainable development.

Scherer et al. (2017) introduced a detailed content analysis study on conceptual frameworks that are used in Earth systems education. They collected the instructional methodologies and systems frameworks that are commonly used in Earth system education. After reviewing 27 papers on the subject they came up with four distinct conceptual frameworks: "Earth systems perspective, Earth systems thinking skills, complexity sciences and authentic complex Earth and environmental systems" (p 477). Related subtopics, limitations and strengths were presented in this research. Authors classified "Earth systems thinking skills" framework as the most employed framework among these four groups. This framework stepped forward by having specific systems thinking abilities described in "Systems Thinking Hierarchical Model" of Ben-Zvi Assaraf and Orion (2005). In conclusion, the researchers proposed that using different frameworks for Earth system education provides improvement of students' understandings (Scherer et al., 2017). They also proposed an instructional model to be used in Earth system education in a consecutive study based on their findings (Holder, Scherer & Herbert, 2017).

As the previously described study (Scherer et. al., 2017) suggested, Ben-Zvi Assaraf and Orion's research (2005), is distinguished from the other papers in the subject of systems thinking. In their research authors presented a new curricular program, named as "Blue Planet", issues "hydro cycle" and studied with 50 junior high school students in eighth grade in Israel, to discover the students understanding of the complex systems, and their capacity to cope with systems (Ben-Zvi Assaraf & Orion 2005). They examined systems thinking in terms of eight characteristics. They used three different Likert-type questionnaires, drawing analyses, word association, concept map, interviews, repertory grids and observations as research tool. The results showed that students made progress in their systems thinking abilities during the period of implementation. They concluded that conceptual understandings and amount of their participation influenced students' development in systems thinking.

Another study conducted with fourth grade Israeli students by Ben-Zvi Assaraf and Orion (2010), with using inquiry-based teaching method in hydro cycle concept, was aiming to reveal whether students in elementary level can achieve system thinking skills. Authors found out that the systems thinking ability increased during the implementation even though students show low levels of systems thinking skills at the beginning of the study. They argued that real life experiences on a subject made students more competent in systems thinking and understanding the relationships between the parts of a system. However, they noted that most of the 4$^{th}$ graders could not complete all levels of STH model because systems thinking represents a higher order thinking skill.

Accordingly, Orion (2007), discussed that activities based on earth systems are more effective than "science for all" paradigm, and presented the holistic approach as tool for understanding the earth systems. He stressed that presenting Earth as a system is resulting in better learning for students than the traditional approach.

In another study, which employed an interpretation of the Ben-Zvi Assaraf and Orion's (2005) model, authors explored the effect of using simulation on improvement of systems thinking skills (Evagorou et al. 2009). The research was conducted with thirteen elementary school students who were tested before and after the implementation of the simulation-based learning environment. According to their findings researchers concluded that simulations could offer a rapid and uncomplicated procedure to experience systemic relations. Despite this, they also noted that simulation is not enough in conceptualizing the dynamic relations within the system.

Shepardson et al. (2014), conducted their study in the context of climate system. Forty-two 7$^{th}$ grade students attended in the study with the purpose of understanding their conceptualization of climate system. Authors argued that in order to develop an understanding on interdependent and connected systems,

climate system could be a suitable example. They used different writing prompts about climate system, greenhouse gases and global warming. According to students' written responses it was concluded that students mostly conceptualize climate as a linear structure, instead of a connected body. Based on the findings of the study and the authors proposed a conceptual model which shows the linkages between the components of the climate system. They argued that this model could be adopted into the curriculum and help to challenge students to build an integrated and interconnected understanding of climate system.

Roychoudhury et al. (2017), published another study on development of the climate system. They designed a 9-11 weeks course program for 7$^{th}$ and 8$^{th}$ graders, including six different topics on climate system. They developed a questionnaire to assess the results of the implementation. The results indicated that the implementation improves the understanding of climate in students. Nevertheless, there was still lack of understanding for interconnectedness of the climate system. Researchers concluded that systems thinking could be studied in terms of curriculum development, pedagogy, assessment and teacher education.

Eilam (2012), also discussed systems thinking in terms of learning ecology and worked with fifty 9$^{th}$ grade students to uncover their systemic understanding in feeding relations. Results of the study indicated that students define a comprehension of components of the system, the operations inside of it and their roles in the system and interactions within the components. On the other hand, the author noted that most of the students still show broken conceptions about the issued system. He argued that systems thinking requires knowledge about components and hidden concepts within the system.

A more recent study (Batzri et al., 2015), implemented in order to uncover the systems thinking abilities of geology major students in terms of dynamic and

cyclic thinking provide evidences to support Eilam's (2012) work. The research group composed of students from geology or physical geography departments and students who are unrelated to geology major used as control group. The results indicated that because geology students are aware most of the components of the Earth systems, they are more acquainted with dynamic relations of the systems in nature, than students who have no geology knowledge.

Hmelo- Silver and Pfeffer (2004) studied a different perspective in systems thinking. Even though they also argued the importance of systems thinking approach for understanding complex systems, these authors examined systems thinking with "structure- behavior- function (SBF) theory" and they investigated the conception aquatic systems with their sample. In this theory, structure represents the different parts of the system, behavior represents the way of working within the system and function represents the task of those parts in the system. Participants included $7^{th}$ grade students, pre-service teachers and the experts in aquatic field. This study concluded that most of the participants were able to perceive the structures, but comprehension of functions and behaviors are only common in experts group.

Influence of experiential knowledge in systems thinking ability also studied by Garavito- Bermúdez, Crona and Lundholm (2014). This research examined the systems thinking abilities of fishers' in terms of ecology and how this knowledge is formed. Authors used the SDF framework, an adaptation of SBF framework used by Hmelo- Silver and Pfeffer (2004), and studied with 14 fishers' in Lake Vattern, Sweden. Findings of the study remarked the importance of the conceptual knowledge. Even though fishers' experience helps them to cover the components of the system and resources in the system, the lack of cognitive background still necessary for dealing with a complex system.

## 2.3.Systems Thinking Skills and Teachers

There are also studies present in the literature which subjects teachers and teacher education. One of the most recent and detailed studies on systems thinking in teacher education submitted by Karaarslan (2016). In this study researcher introduced systems thinking as a main skill to become an education for sustainable development educator. The gap analysis in the research provided that systems thinking is a necessary skill to be an education for sustainable development educator. Depending on this evidence an outdoor course for science teacher education with mapping as measurement tools. Findings implied that outdoor course could support the improvement of essential systems thinking skills to be an ESD educator. On the other hand, the systems thinking skill levels of the participants found to be dependent on their personal backgrounds and complexity of systems thinking skills.

In another research practiced with student teachers, Schuler et al. (2017), conducted a study which combines systems thinking and pedagogical content knowledge. Authors proposed a model composed of four competence dimensions on systems thinking named "Freiburg heuristic competence model" in their article. They aimed to measure systems thinking and pedagogical content knowledge on teaching systems thinking of teaching students. They worked with four different groups of student teachers from biology and geography departments for implementation. The key part of the study was different course designs to implement systems thinking from different perspectives, technical and didactic. With using pre-tests and post-tests, authors concluded that there is no significant difference between these two interventions. However, with the help of the control group they concluded that there is a significant achievement in systems thinking of student teachers after the implementation. Findings of the study supports the development of systems thinking and pedagogical content knowledge in system thinking during teacher education.

Lee (2015), examined the relation between teachers' use of representational models and their levels of systems thinking skills. The study was designed as a two-staged study with this aim. In the first stage sixty-seven in-service and sixty-nine pre-service science teachers analyzed in terms of their cognitive knowledge on water cycle and their systems thinking levels. The researcher developed a rubric based on the systems thinking skills presented in the "Systems Thinking Hierarchy Model" of Ben-Zvi Assaraf and Orion (2005). The evidence gathered by semi-structured interviews showed that there is not a specific difference in systems thinking levels of pre-service and in-service teachers. However, there were struggles to achieve certain systems thinking abilities like identifying the components, processes and connections, finding out the hidden dimensions and humans' influence on the system. In the second stage, researcher investigated the in-service and pre-service science teachers' use of visual representation in the water cycle subject. In both teacher groups it was observed that there is not a remarkable use of visual representations. As a result, the author made a connection between participants' low levels of systems thinking and poor implementation of visual representation in class. It is suggested that in order to raise students as systems thinker, both teachers, competence on systems thinking and the instructional method holds an important value.

Systems thinking competencies of teachers also issued in the paper of Ateskan and Lane (2017). Authors presented a professional development program that aimed to raise the systems thinking abilities of science teachers which is not very common in the literature. Thirty-nine in-service teachers attended the eight months long program. The implementation started with a summer workshop which consisted of hands on activities, presentations and field trips. As a continuation of the workshop, teachers introduced the activities they had experienced during the workshop to their students and implemented projects in their classroom. Pre- and post- questionnaire and concept maps were used to measure the improvement of systems thinking skills after workshop. A rubric

developed by Karaarslan (2016) was used in the evaluation of concept maps. The questionnaire results indicated that workshop provided significant increase in participants' systems thinking skills. On the other hand, concept maps showed that participants still not able to identify all aspects of sustainable development.

In conclusion, it was noticed that literature on systems thinking in education points out the gap in the systems thinking in teacher education and in-service teaching. In general, systems thinking is encountered in studies done with students from primary, elementary and high school, and college. Most of these research embraces teaching practice as a divided subject from the students' education. On the other hand, the research designs that deal with teachers imply the absence of studies with in-service and pre-service teachers (Ateskan & Lane, 2017**;** Karaarslan, 2016).

### 2.4.Assessment of Systems Thinking Skills

About the evaluation of systems thinking skills, literature points out several instruments. Concept maps are one of the instruments that steps forward to assess systems thinking. In their research, Brandstadter et al. (2012) evaluated different concept mapping applications. One hundred fifty-four fourth grade students and ninety-three eighth grade students were participated in the study. Students were involved in three different types of concept mapping applications which were "highly directed computer mapping", "highly directed paper-pencil mapping" and "non-directed paper-pencil mapping". Researchers chose concept maps as an instrument to measure systems thinking based upon the idea that systems thinking involves conceptualization and interrelations of the system. They found out changing medium of concept maps from paper-pencil to computer does not have significant effect. On the other hand, giving the students selected concepts and linking words during the concept mapping practice has remarkable benefits.

Similarly, Tripto et al. (2016), examined interviews as a measurement instrument for evaluating systems thinking ability. The paper utilized the systems thinking hierarchical model (Ben-Zvi Assaraf &Orion, 2005) into the human body system. Authors studied with eighty-three $11^{th}$ grade student in the context of biology course. Participants interviewed both explicitly and non-explicitly with the aim of finding out the effect of these two interviewing methods on the measurement of systems thinking. Results of the research indicated that explicit interviewing directs participants to find out more specific and distinct connections in human body system. Accordingly, reflection interviews were found to be effective instruments in terms of evaluating systems thinking skills of students.

# CHAPTER 3

# METHODOLOGY

Methodology section gives information about the structure of the study. Research design, participants of the study, instrumentation, pilot study, main study, data collection process, data analysis, validity, reliability and ethics, and limitations of the study were presented consecutively in this section.

## 3.1.Research Design

This study aims to draw an in-depth conclusion about the Turkish pre-service science teachers' STS levels. As Karaarslan (2016) concluded, personal backgrounds of the participants could have an impact on their STS levels. Therefore, in this study, they are studied as different cases.

With this recommendation in mind, case study design as a part of qualitative research is applied in this study. It is stated that an individual, a group an institution or an event could be studied as a case (Fraenkel, Wallen, & Hyun, 2012). Additionally, Stake (2005), defined case study as a questioning process not only deals with the selected case, but also deals with the results of this questioning process. Moreover, case study design facilitates to focus on experiential knowledge and the resources this knowledge is influenced by (Stake, 2005).

The currently presented research is designed as a multiple case study. In this type of case study design, the cases are used for examining a general situation, while a specific case is not at the focus of interest. The cases are used to draw a collective conclusion instead of explaining only a single-case (Stake, 2005).

Merriam (2009), asserts that, in multiple case studies, each case can have common characteristics, like being part of a community or a situation. Accordingly, in this research the six participants were selected amongst the senior science education students from a prominent Turkish university. Each participant was analyzed as a separate case and the data obtained from the analysis was used for understanding STS levels of pre-service science teachers.

With investigating the several numbers of different cases, researcher might be able to provide more compelling conclusions at the end of the study (Fraenkel et al., 2012). In addition, Merriam (2009), also states that multiple cases increase the validity and reliability of the results, alongside the generalizability. On the other hand, they require large amount of time and resources (Fraenkel et al., 2012).

### 3.2.Participants of the Study

For this study, six (female) pre-service science teachers were selected purposively. Participants were members of one of the most prominent universities in Turkey. In order to provide purposive sampling there were three criteria considered in participant selection:

1- University: Participants were attending in the same university in Turkey. Being part of the same university enables them to share similar academic backgrounds.

2- Level of education: All participants were selected amongst the 4th year students of science education department. This criterion made sure that all of them has taken the compulsory course related to ESD.

3- Recommendation: The students who are interested in ESD were suggested to the researcher by the instructors. Voluntary participants were selected amongst this group.

Participants' ages ranged between 23 and 25. All of them have taken the compulsory course on environmental sciences their department. In addition, two of them have taken different elective courses also related with ESD. Also, participants' personal backgrounds were not considered during sampling. For example, while one of them has been grown up in a city without any connection with nature, another one has grown up in a house with garden and developed conceptions on natural cycles due to her observations.

With the aim of ensuring the confidentiality of the participants' identities, pseudo names were used to describe participants. Table 3.1 shows the demographic data of the main study participants.

*Table 3.1: Demographic data of main study participants*

| Name | Age | Taken ESD related courses | Hometown |
|---|---|---|---|
| Tuba | 23 | Compulsory environmental science course<br>Elective course on sustainability and education given by department of elementary education | Small town |
| Ebru | 25 | Compulsory environmental science course | Small town |
| Aslı | 24 | Compulsory environmental science course | City center |
| Burcu | 23 | Compulsory environmental science course | Small town |
| Yaprak | 23 | Compulsory environmental science course<br>Elective course on sustainability and climate change given by department of elementary education | City center |
| Deniz | 23 | Compulsory environmental science course | Village |

### 3.3.Instrumentation

A real-life scenario and associated interview questions were developed and used as the instruments in this research.

#### 3.3.1. The Real-Life Scenario

The real-life contexts provide better understanding of sustainable development and increase the consciousness for self-actions (Tilbury, 2011). Besides, it was observed that there are other studies that use the real-life scenarios (Erdoğan & Tuncer, 2009; Karaarslan, 2016). Erdogan and Tuncer (2009), mentioned that real-life scenarios provides a perspective for developing a personal relation with the scenario.

In this thesis, the real-life scenario was selected considering its representativeness of sustainable development. The scenario was presenting a news from Kızılırmak basin in Turkey. The text was developed from the newspaper article titled as *"Buffalos will save the Kızılırmak basin"* (Sönmez, 2010). The researcher supported the article with additional information from other sources to provide a wider perspective about the context. The text was explaining the decrease in buffalo population in the Kızılırmak basin over years. When buffalo products lost their economic value, more and more buffalo breeders leave their profession and started to engage in agriculture. However, the chemical that are used in agriculture and changing ecosystem due to lack of buffalos, people in the area started to face with environmental problems. In order to solve these problems a non-governmental organization organized a project in the area. The project aimed to increase buffalo population with production and marketing of traditional buffalo products, training buffalo breeders to use technology, and organizing local festivals to increase publicity of the Kızılırmak basin. The scenario can be found in the Appendix A.

This scenario was selected because it involves all aspects of sustainable development (environmental, economic & social) and implicitly it portrays the system in the area. It points out the environmental aspect with the emphasis on environmental importance of buffalos and ecosystem; economic aspect with the emphasis on the economic value of buffalo products and marketing; and social aspect with the emphasis on traditional buffalo products and local festivals. The scenario provides systemic connections with telling how ecosystem changed in accordance with the decrease in buffalo population.

### 3.3.2. Interviews

For qualitative studies in education interviewing defined as one of the most frequently used instruments. It could even be used as the only instrument of a study (Merriam, 2009). As Patton (1990) indicated, interviews aim to discover the attitudes, feelings, thoughts, plans, experiences and worldview. In other words, the things that cannot be observed from outside. As a case study which purposes to acquire a deeper understanding about the participants' systems thinking skills, in this study interviews forms the bases of data collection. Interviewing will be used to investigate participants' interpretation about the real-life scenario to understand their systems thinking capacities.

Semi-structured interviews used in this thesis. This interview type is characterized with their adaptable questions and order (Merriam, 2009). For Patton (1990), the truly open-ended questions do not have directive wording or dichotomous expressions. Accordingly, the interview questions in this study were designed as implicit questions to avoid influencing participant's answer. Moreover, for some STSs, researcher used several different questions to gain more insight on participant's thoughts. In order to provide the adaptability, questions were built as open-ended questions. The researcher arranged the order and expressions for all questions to make sure taking necessary responses from each interviewee.

The interview questions were shaped in their final forms with revision of Karaarslan (2016)'s and Lee (2015)'s interview questions, experts' advisory and pilot study. Two professors from science education department who were specialized in education for sustainable development provided consulting as experts during the study.

Six demographic questions were designed to explore on participants' personal background. Additionally, 20 open-ended questions, related to the real-life scenario were designed to explore the participants' systems thinking skills. Within those 20 questions some questions specifically asked for certain STSs while some of them have potential to provide evidence for every STS. For example, the first and second questions were asked to gather a general answer that may be used in evaluating any STS. On the other hand, there was no specific questions defined for STS 4 and STS 5. Researcher traced evidences for these STSs in all responses. Additionally, two of them specifically asked to understand participants' systems conception. An interview guide was prepared by the researcher prior to the interviews (Table 3.2). The interview questions can be found in the Appendix B.

*Table 3.2: Interview Guide*

| Interview Questions | Measured Systems Thinking Skills |
|---|---|
| 1- What is the main idea of this case?<br>2- What do you understand/infer from this case? | No specific STS measured. Answers used for evaluating all STS. |
| 3- What are the components of this case?<br>4- What are the key words of this real-life case? | STS 1- Identify components of a system and processes within the system |
| 5- How many small incidents related to each other in this real-life case? What are the headlines of them?<br>6- Could you draw a concept map (or picture) to show the relationships among these components, and explain your drawing?<br>7- What are the effects of the changes in this real-life case? What are the positive and negative sides? | STS 2- Identify relationships among the system's components |
| 8- Could you suggest a title for this case?<br>9- What can you say about the communication between man and environment, based on this real-life case?<br>10- What can you say about sustainable development based on this case? | STS 3- The ability to make generalizations |

*Table 3.2 (Continued)*

| | |
|---|---|
| 11- Could you describe the future of Kızılırmak, assuming people are engaged in agriculture instead of buffalo farming?<br>12- Could this real-life case be a threat to the human life and nature, in present and future?<br>13- Could the situation described in this case be a threat to the sustainable future? | STS 6- Thinking temporally: Retrospection and prediction |
| 14- Would there be any effect of raising the population of water buffalo in Kızılırmak delta? How?<br>15- If you were a buffalo farmer who lives in Kızılırmak delta, how would you react to this problem? | STS 7- Developing an empathy with other people and non-human beings |
| 16- How would you design a project to solve the problems of the Kızılırmak delta? | STS 8- Recognizing own responsibility in the system |
| 17- What does Kızılırmak means to you?<br>18- Is Kızılırmak delta an important place for you? Why? | STS 9- Developing a sense of place |
| 19- What is a system?<br>20- Can you give an example to a system? What are the features that show that this is a system? | Answers used to analyze systems concepts of participants. |

### 3.4.Pilot Study

Pilot studies were conducted with five purposes: to test and develop the interview questions, to test the effectiveness of the real-life scenario (explained in section 3.3.1.), to determine the STSs for the research, to help development of rubric for analysis and finally allow researcher to practice the interviewing process.

Pilot interviews were held during the spring semester of 2015-2016 academic year. Three (two females, one male) 4th year, pre-service science teachers from the education faculty of the same university volunteered to participate in pilot interviews. For each participant, interviews took one hour approximately. Interviews were audio recoded with the permission taken from interviewees. Audio-recordings were transcribed and analyzed to evaluate the selected real-life scenario, the interview questions, and the STSs initially selected for the research. Expert opinions were taken during that evaluation process.

Ultimately, continuing to the main study with the selected scenario is determined. In terms of gaining more clear responses from the participants, some additions and removals made into the interview questions and STS. While there were eight STSs and 14 interview questions initially in the study, there were nine STSs and 20 interview questions defined after pilot interviews. In addition, the analysis rubric for STSs also developed in the light of pilot results.

### 3.5.Main Study

After pilot study, instruments and data analysis tools were revised and gained their final forms. The instruments used in the main study were explained in the section 3.3. The participants explained in the section 3.2 were participated in the main study. Following sections are explaining the data collection and data analysis procedures of the main study.

### 3.6.Data Collection

Merriam (2009) noted that in qualitative research, researcher is the principal instrument. Accordingly, in this study, researcher participated in the all data collection process and conducted all interviews in person.

Main study interviews were conducted during the spring semester of 2016-2017 academic year. Conducting the interviews at the end of the last semester of undergraduate study, enables researcher to make sure that all participants have taken the mandatory courses of their department. Interview process took five days with approximately one hour for each participant.

Before every interview all participants were signed a volunteer participation form which gives brief information about the study and notes that they have a right to quit the interview if there is a disturbing question. Also, they were asked for their consent for audio recording of interviews.

Interviews were conducted in a quiet and comfortable place to provide participants a relaxed environment. Additionally, in order to get accurate responses from participants, real-life scenario and interview questions was presented in Turkish, native language of all participants.

At the beginning of the interviews the real-life scenario was given to the participants. After they read the text and ready to interview, participants were asked the six demographic questions, 20 open-ended questions related with the nine systems thinking skills. Even though there is an interview guide prepared by researcher, by the nature of semi-structured interviews, sometimes participants made statements about some STSs in different questions other than corresponding questions.

## 3.7.Data Analysis

Data obtained from the interviews were analyzed in consideration of systems thinking skills defined in the research with using the rubric developed for this study. For analysis, each interview was transcribed, and transcriptions were reviewed number of times. Interview transcripts were used for coding, regarding the systems thinking skills. Coding was performed with the using the categories and definitions for each STS (Table 3.3).

Following two sections provide explanations for the nine systems thinking skills measured in the research and the data analysis rubric developed based on these nine STSs.

### 3.7.1. Systems Thinking Skills Measured in the Research

The systems thinking skills defined and measured in this research determined according to the pilot interviews and expert opinions. Eventually, nine STSs are decided to be employed. This research initially set its basis on Ben-Zvi Assaraf and Orion's "The Systems Thinking Hierarchical Model" (2005). In this model, authors presented eight systems thinking characteristics and divided them into three levels hierarchically. The pilot interviews were used to revise the suitability of these eight skills to the given sustainable development scenario. Accordingly, it is observed that 3$^{rd}$ skill: "the abilty to identify dynamic relationships within the system" and 4$^{th}$ skill: "the ability to organize the systems's components, processes and their interactions within a framework of relationships" of Ben-Zvi Assaraf and Orion's model are unsuitable for the context of sustainable development. Furthermore, in the light of the responses of the pilot study interviews, it was decided to employ the sixth, ninth, tenth, eleventh systems thinking skill identified by Karaarslan (2016). However, the ninth and tenth skills, which are "developing empathy with other people" and "developing a sense of place" was adopted as a single STS for this study. As a result, there were nine systems thinking skills defined for the main study.

The first skill, “identify components of a system and processes within the system” has been adapted from Ben-Zvi Assaraf and Orion (2005)’s model. Ben-Zvi Assaraf and Orion (2005) presented this STS as the ability to identifying components of the water cycle. It is implemented in the current study as ability to identifying components of sustainable development (which are categorized as environmental components, economic components and social components) in the given scenario.

The second systems thinking skill, “identify relationships among the system’s components”, has been defined in Ben-Zvi Assaraf and Orion (2005) as the recognition of the connections between different components of the water cycle. The researcher adapted this skill into the current study as finding out the relationships between different components of sustainable development.

The third skill is “the ability to make generalizations”. Ben-Zvi Assaraf and Orion (2005), described this skill as the ability to implement the system’s characteristics into different contexts. Accordingly, in this research participants are expected to generalize the components of the given scenario, considering environmental, economic and social aspects of sustainable development. For example, the local water pollution told in the scenario, may be connected to global water problems.

The forth skill “understanding hidden dimensions of the system”, is explained by Ben-Zvi Assaraf and Orion (2005), as the ability to identify components and connections that are not presented explicitly.

The fifth skill “the ability to understand the cyclic nature of the systems” is indicates that the world is composed of cyclic relations and systems are presentations of these cyclic relations (Ben-Zvi Assaraf & Orion 2005). In the original study the Ben-Zvi Assaraf and Orion defines the natural cycles, i.e. water cycle, carbon cycle, as systems in nature. Researcher used this skill as

understanding the cyclic relations amongst the environmental, economic and social aspects of sustainable development.

The sixth skill “thinking temporally: retrospection and prediction” is also the last skill obtained from Ben-Zvi Assaraf and Orion (2005)’s model. This skill indicates the recognition of the interactions of present, past and future interactions. For this research participants are expected to predict future influences of the scenario, in terms of the three aspects of sustainable development.

The seventh skill “developing an empathy with other people and non-human beings” is adopted from the Karaarslan (2016)’s research. In the original study, this skill was presented in two different skills; which are “developing empathy with other people” and “developing empathy with non-human beings”. These two skills emerged from the need of understanding the perspectives of others (Karaarslan, 2016). As stated by Karaarslan (2016), systems thinking can be an approach to develop empathy with components of the system, which are both people and non-human beings. Considering the findings of the pilot interviews, researcher also find useful to add the empathy skills into current research. However, the context of the selected scenario is not appropriate to evaluate them individually. Therefore, empathy skills of Karaarslan (2016), transferred into this research as a single system thinking skill.

The eight skill is “recognizing own responsibility in the system”. This skill was adopted from Karaarslan (2016)’s study. It was described as recognition of the personal role in the global issues, and ready to take action for solutions to these issues. Because this skill includes personal choices and responsibilities, it is also related with how participants make personal connections with the global problems.

The last skill, “developing a sense of place” was also identified by Karaarslan (2016). It is the ability to identify different dimensions of the place. It was adapted from the Ardoin (2006)’s study about defining a place considering different meanings that are biophysical, political, psychological and socio-cultural contexts. All these different dimensions of the place are interconnected as stated by Karaarslan (2016). It is found relevant with the current research because the presented scenario was built on a specific place.

For all these nine systems thinking skills researcher presented categories and definitions in the context of sustainable development. They are presented in the Table 3.3.

### 3.7.2. Rubric Development

After determining the STSs and real-life scenario a rubric was developed to determine the STS levels of pre-service science teachers. During the rubric development researcher used the responses of the pilot interviews, relevant literature and opinions of two experts on ESD.

For each systems thinking skill, three levels were determined; Level 1, Level 2 and Level 3. Necessary requirements to achieve each level were explained explicitly in the rubric. The rubric is presented in Table 3.4.

*Table 3.3: Systems Thinking Skills, Categories and Definitions*

| STS | Category | Definitions |
|---|---|---|
| STS 1- Identify components of a system and processes within the system | Components<br>Environmental components<br>Social components<br>Economic components | Environmental components include issues like; natural resources (water, energy, agriculture and biodiversity), climate change, disaster preventions, rural development, sustainable urbanization, disaster prevention, mitigation<br>Social components include issues like; human rights, gender equity, cultural diversity<br>Economic components include issues like; poverty, corporate responsibility & accountability, market economy (UNESCO, 2006; Karaarslan, 2016). |

*Table 3.3 (Continued)*

| | | |
|---|---|---|
| STS 2- Identify relationships among the system's components | Connections<br>Connections between environmental components<br>Connections between social components<br>Connections between economic components<br>Connections between environmental and economic components<br>Connections between environmental and social components<br>Connections between economic and social components<br>Connections between environmental, economic and social components | To find out the connections between different components derived from the scenario and explain how they influence each other. They can be directly pointed out in the text or not. For this scenario the effect of water pollution on buffalo farming, or relation between occupation and education might be examples. |
| STS 3- The ability to make generalizations | Generalizations<br>Generalizations on environmental aspect<br>Generalizations on economic aspect<br>Generalizations on social aspect | Internalizing the system's core mechanism and transferring to this knowledge or conception into other contexts (Ben-Zvi Assaraf & Orion, 2010). |
| STS 4- Understanding hidden dimensions of the system | Hidden dimensions | Awareness of the systems components which are not directly pointed (Ben-Zvi Assaraf & Orion, 2005). |

*Table 3.3 (Continued)*

| | | |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Cyclic nature of the system | Comprehension of the cyclic nature and ongoing cyclic processes around the world (Ben-Zvi Assaraf & Orion, 2005). |
| STS 6- Thinking temporally: Retrospection and prediction | Predictions<br>Future predictions on environmental aspects<br>Future predictions on economic aspects<br>Future predictions on social aspects | Recognizing the fact that in present reactions in the systems either result of a past action or cause of a future impact ((Ben-Zvi Assaraf & Orion, 2010). |
| STS 7- Developing an empathy with other people and non-human beings | Empathy<br>Empathy with other people<br>Empathy with non-human beings | Empathizing with other people with understanding their motivation's and feelings and showing empathy toward non-human beings in nature (Karaarslan, 2016). |
| STS 8- Recognizing own responsibility in the system | Personal relation<br>Making connection between issue and personal life<br>Taking responsibility | Acknowledging the personal role and responsibility in the global issues or problems (Karaarslan, 2016). |
| STS 9- Developing a sense of place | Sense of Place<br>Biophysical dimension<br>Psychological dimension<br>Sociocultural dimension<br>Political / Economic dimension | Recognizing a place bears different meanings and can be evaluated in different dimensions. The four dimensions are biophysical environment, psychological environment, sociocultural and political context. (Ardoin, 2006; Karaarslan, 2016) |

*Table 3.4: Analysis Rubric*

| STS | Evaluation Criteria | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | It is expected from the participant, to list the components and processes about three aspects of sustainable development taking place in the scenario. | Identifies components from one aspect of sustainable development (e.g. Only environmental components) | Identifies components from two aspects of sustainable development (e.g. Environmental and social components) | Identifies components from all three aspects of sustainable development (e.g. Environmental, social, and economic) |
| STS 2- Identify relationships among the system's components | Participants are expected to find connections between different components of the scenario. | Identifies relationships within the same aspect of sustainable development (e.g. Only environmental-environmental relations) | Identifies relationships among two different aspects of sustainable development (e.g. relationships between environmental – social components) | Identifies relationships among three aspects of sustainable development: environment, economy, society |

*Table 3.4 (Continued)*

| | | | | |
|---|---|---|---|---|
| STS 3- The ability to make generalizations | Participants are expected to generalize the scenario into other contexts with considering environmental, social and economic components of sustainable development. | Identifies one aspect of sustainable development while making generalizations | Identifies two aspects of sustainable development while making generalizations | Identifies three aspects of sustainable development while making generalizations |
| STS 4- Understanding hidden dimensions of the system | Participants are expected to identify components and processes that are not directly stated in the scenario but could be affected by the events that are mentioned in the scenario. | Identifies one hidden dimension from the scenario | Identifies two hidden dimensions from the scenario | Identifies three or more hidden dimensions from the scenario |
| STS 5- The ability to understand the cyclic nature of the systems | Participants are expected to show cyclic relations between components on their concept maps AND/OR to define a cyclic relation for the events and processes in the scenario. | Not explain any cyclic relation in the scenario | Explains cyclic relations in the scenario but does not includes all aspects of sustainable development. | Explains “cyclic” relations in the scenario and contains three aspects (environment, economy, society) |

*Table 3.4 (Continued)*

| | | | | |
|---|---|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Participants are expected to predict the future influences of the events that are presented in the scenario. | Makes future predictions for only one aspect of sustainable development | Makes future predictions for two aspects of sustainable development | Makes future predictions for three aspects of sustainable development |
| STS 7- Developing an empathy with other people and non-human beings | Participants are expected to show empathy to people and non-human beings who are issued in the scenario. | No empathy with other people and non-human beings | Struggle to develop empathy with both other people and non-human beings | Considers other people's perspective and non-human beings in a complete way |
| STS 8- Recognizing own responsibility in the system | Participants are expected to define their role for the issue presented in the scenario and takes responsibility. | No connection between issue and personal life | Struggle to make connections between issue and personal life &taking responsibility | Makes connections between issue and personal life and takes responsibility |
| STS 9- Developing a sense of place | Participants are expected to define different meanings to the place in the scenario. | Defines place as including 1 dimension | Defines place as including two dimensions | Defines three or more dimensions |

### 3.8.Validity, Reliability and Ethics

To obtain validity of the instruments in this study, content-related evidence was used. Content-related validity ensures the appropriateness of the instruments with comparing the content and format (Fraenkel et al., 2012). In this thesis, the scenario and interview questions were presented to two professors from elementary science education department who were specialized in education for sustainable development. Additionally, researcher bias could be a threat to internal validity in this study. Standardized open-ended interviews enable comparison between answers of different participants and enables to decrease the researcher bias (Patton, 1990). In this study, interview questions were designed as open-ended questions as suggested.

Reliability in social sciences studies is hard to achieve because people tend to show unstable behaviors. Therefore, it is not expected to develop behavioral laws with qualitative study, rather providing explanations is the major motive (Merriam, 2009). In order to obtain reliability in this research, researcher used a rubric to analyze the interviews. Transcripts, rubric, and codes were examined several times to ensure the results are consistent.

To prevent ethical concerns for this thesis, instruments were presented to the ethics committee prior to the data collection (See approval form in Appendix C). In addition, all participants were informed with a volunteer participation form about they can leave the study if they are disturbed during the interview. Participants' permissions for audio recording was obtained by signed consent forms.

### 3.9 Limitations

The currently presented thesis has several limitations. Firstly, all pre-service science teachers who participated in the study were female. This choice was not purposeful, rather it was the most likely sample because the number of male pre-service teachers were not high in the department where study conducted. Thirdly, results of study cannot be generalized because it was designed as a qualitative case study. Findings of this study was limited with the six participants' interviews. Lastly, participants were limited with the context given in the scenario and interview questions were implicit. The text might constraints participants' thinking Therefore there might be some missing about participants perception.

# CHAPTER 4

# FINDINGS

The six participants of this study were examined as individual cases. Therefore, findings of this study will be presented for each case separately. For each participant interviews were analyzed according to the rubric presented (see the section 3.7.2. Rubric). Based on the analysis of interviews system thinking levels of participants were determined.

For each case, firstly, demographic data will be presented. Then demographic data will be followed by detailed analysis of nine systems thinking skills, participant's definition of system and evaluation part. Necessary quotations from the responses of interview questions were added in each part to support the findings.

## 4.1.CASE 1: TUBA

### 4.1.1. Tuba's Demographic Data

Tuba, is a 23-year-old senior year student from the elementary science education department of one of the well-known universities in Turkey. She has grown up in outskirts of a small town, in a house with a garden. In primary school she attended the activities of a non-governmental organization that works about environmental protection. She joined garbage collection activities with this non-governmental organization to raise awareness among people.

Tuba took two courses about environment and sustainability, one of them is the mandatory environmental science course and the other one is an elective course about education and sustainability. She did not hear anything about the given scenario.

### 4.1.2. Tuba's System Thinking Skills

Tuba's levels for each systems thinking skill is determined as a result of the responses to the interview questions. Findings are presented for each STS separately in this section.

#### 4.1.2.1.STS 1- Identify Components of a System and Processes Within the System

First systems thinking skill includes identifying components and processes within the system. In this study participants were expected to identify components and processes from each aspect of sustainable development (environmental, social, economic) within the given scenario. When she is asked to identify the components and the key words of the scenario (Questions 3 & 4) she identified several components and processes in her responses.

> "Human, economy and environment. Also, plants and animals are in the environment…" (Question 3).

> "Decrease in buffalo population, occupations of people in the region, change in Kızılırmak ecosystem, pesticides, chemicals, living organisms in the region like birds and plants, sustainability, raising awareness among people in the region and the project (mentioned in the scenario)." (Question 4).

Components and processes identified by Tuba was categorized as environmental, social, and economic *(Table 4.1).* It is observed that she only failed to name process for economic aspect, but she achieved to list components from all three aspects. Accordingly, she was classified in Level 3 for STS 1.

*Table 4.1: Tuba's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental<br>Components: nature, plants, animals, pesticides, chemicals, other living organisms in the region (birds, plants etc.)<br>Processes: decrease in buffalo population, change of Kızılırmak's ecosystem | Social<br>Components: Human, projects,<br>Processes: raising awareness *(among people in the region)* | Economic<br>Components: Economy, occupations of people in the region (agriculture, animal farming etc.)<br>Processes: No economic process identified. | Level 3: Identifies components and processes from all three aspects of sustainable development |

**4.1.2.2.STS 2- Identify Relationships Among the System's Components**

Second systems thinking skill is about identifying the relationships within the system's components. Participants were expected to identify relationships within different components and processes in the given scenario about Kızılırmak basin. Responses for questions 5 and 6 were used to determine Tuba's level for STS 2. Quotations below shows the connections found by the participant.

> "*(plants- animals)* Firstly, plants and animals are in relation in the Kızılırmak region… *(income- social status, income- education)* Farmers earn their keep from Kızılırmak basin. Accordingly, their social status and quality of their children's schools depend on their income... *(agriculture- economy)* They [farmers in the Kızılırmak

basin] might turned wetlands into agricultural lands in an attempt to earn more money... *(agriculture- job opportunity- internal migration connection)* When more people are engaged in agriculture, agricultural mechanization could develop in the region. Consequently, people will be affected because there would be not enough jobs for everyone in the agricultural fields. As a result, there might be internal migration out of the Kızılırmak region. Besides, chemicals [used for agriculture] will also increase and there will be more pollution... *(Pollution- health-government economy connection)* The water in the Kızılırmak river is used for drinking water in some cities in Turkey. If there is an epidemic illness because of pollution of the river, the government economy will be affected… *(agriculture- national economy)* If a proper agricultural method was used in there [Kızılırmak], it may support our [Turkey] economic growth." (Question 5)

"*(environmental pollution- agriculture)* Farmers used pesticides for agriculture and it lead to environmental pollution.... *(buffalo population- other species)* There is food chain in the Kızılırmak region. When buffalo population decrease it might lead to loss of other living organisms.... *(Water pollution- biodiversity)* Chemicals do not only pollute the soil but also pollute the water. Water pollution might cause the loss of number of species. … *(buffalo breeding- economic growth)* Government is also interested in the economic activities in the Kızılırmak region. If buffalo breeding would improve, they [buffalo breeders] may export buffalos and national economy would develop... *(economy- internal migration)* If people do not gain enough money, they might leave their homes and migrate to the bigger cities... *(economy- education)* Education is important. Farmers [in the Kızılırmak region] took trainings as a part of the awareness projects. These trainings helped them to learn other buffalo products and different economic channels about buffalo breeding… *(economy-*

*education)* Economy affects every part of life. If a farmer does not gain too much money, their children might not have a chance to go qualified schools… *(economy- health)* Economy affects their health because they are living in suburbs and their hospitals might not be well-equipped as the ones found in bigger cities… *(ecosystem- economic activities)* People are trying to earn their living. They may have found agriculture helpful for gaining more money. However, they change the ecosystem and environment without noticing." (Question 6)

Connections identified in the during the interview were categorized according to the Table 3.3 *(see section 3.7.1.)*. Tuba found four different connections within environmental components, one connections within economic components, two connections between environmental & economic components, four connections between economic & social components. In addition to this, she identified two different connections between all three components of sustainable development. However, there is no connection found within social components and between environmental and social components. These connections are presented in the *Table 4.2*. As a result of the analysis she was classified in Level 3 for STS 2.

*Table 4.2: Tuba's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | plants- animals<br>environmental pollution- agriculture<br>water pollution- biodiversity<br>buffalo population- other species | Level 3: Identifies relationships among three aspects of sustainable development: environment, economy, society |
| | Connections between social components | - | |
| | Connections between economic components | buffalo breeding- economic growth | |
| | Connections between environmental and economic components | agriculture- (national) economy<br>ecosystem- economic activities | |
| | Connections between environmental and social components | - | |
| | Connections between economic and social components | income- social status<br>economy- internal migration<br>economy- education<br>economy- health | |
| | Connections between environmental, economic and social components | agriculture- job opportunity- internal migration<br>environmental pollution- government economy- health | |

#### 4.1.2.3.STS 3- The Ability to Make Generalizations

Third systems thinking skill is about the ability to making generalizations. It is expected from the participants to transfer the characteristics of a system into other contexts. Tuba made a generalization about environment, based on the scenario:

> "This event [loss of buffalo population] might be an example for the other regions of our country. There are other rivers, which also have agriculture and animal farming. This scenario may help to take precautions around these areas to avoid natural deterioration." (Question 7)

It is observed that economic and social components of the scenario was not mentioned in the generalizations made by the participant. Therefore, Tuba was classified in Level 1 for STS 3 (*Table 4.3*).

*Table 4.3: Tuba's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalizations on environmental aspect | Level 1: Identifies one aspect of sustainable development while making generalizations |

#### 4.1.2.4.STS 4- Understanding Hidden Dimensions of the System

Fourth systems thinking skill focused on the hidden dimensions found by the participants, related with the scenario. Hidden dimensions are the components or processes that are not directly pointed out in the text, but still related with the context of the scenario. Throughout the interview Tuba pointed out several hidden dimensions. They are listed in Table 4.4. For example, she defined migration as a dimension of scenario. Additionally, she mentioned education, social status and health during the interview in relation with the scenario.

Because she found out more than three hidden components, she was classified in Level 3 for STS 4.

> *About migration:* "Economy effects every part of their [people in Kızılırmak region] lives. As a result, there might be internal migration out of the Kızılırmak region." (Question 5)
>
> *About education, health and social status:* "Economy affects every part of life. Education, even health. Who has the greater income, white collars or farmers? Probably farmers with small fields gain less money. So, this affects their lifestyle; from their clothing to quality of education for their children. Economy affects their health and wellbeing negatively because the hospitals in the area may not be as well-equipped as the ones found in bigger cities." (Question 6)
>
> *About extinction of endemic species:* "Even though the text does not have any info about them, the endemic species of Kızılırmak may be at risk, too. Changes in buffalo population might have affect them." (Question 6)
>
> *About national economy:* "Government is also interested in the economic activities in the region [Kızılırmak]. If buffalo breeding would improve, they [buffalo breeders] may export buffalos and national economy would develop." (Question 6)
>
> *About sustainable agriculture:* "Agriculture will have devastating effects for the Kızılırmak region. Sustainable agriculture can be a solution to decrease health risks, but water scarcity still will be a problem." (Question 11)

*Table 4.4: Tuba's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Migration<br>Education<br>Social status<br>Health<br>Extinction of endemic species<br>National economy<br>Sustainable agriculture | Level 3: Identifies three or more hidden dimensions from the scenario |

#### 4.1.2.5.STS 5- The ability to understand the cyclic nature of the systems

Fifth systems thinking skill is about understanding the cyclic nature of the system. Understanding cyclic nature means recognizing the continuous and nonlinear relationships between different components of the system. Participants were expected to find out cyclic relations between components from all aspects, environmental- social- economic, of sustainable development. Tuba depicted a cyclic relation in her answer to question 5.

> "All components are in relation. Kızılırmak, plants, animals and humans have a relationship with each other. Farmers earn their keep from Kızılırmak basin. Accordingly, their social status and quality of their children's schools depend on their income. They [farmers in the Kızılırmak basin] might turned wetlands into agricultural lands in an attempt to earn more money. When more people are engaged in agriculture, agricultural mechanization could develop in the region. Consequently, people will be affected because there would be not enough jobs for everyone in the agricultural fields. As a result, there might be internal migration out of the Kızılırmak region. Besides, chemicals [used for agriculture] will also increase and there will be more pollution. It would give more harm to Kızılırmak river." (Question 5)

In her answer, participant mentioned the cyclic interactions between nature, plants and animals (environment), human's lifestyle (society), and job opportunities (economy) in the context of the scenario. Based on her interview and her concept map drawing Tuba was classified in Level 3 for STS 5 *(Table 4.5)*.

*Table 4.5: Tuba's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explanation on cyclic nature of the systems including environment, economy and society. | Level 3: Explains "cyclic" relations in the scenario and contains three aspects (environment, economy, society) |

#### 4.1.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

The sixth systems thinking skill is about understanding the future results of the present actions. Making future predictions containing all aspects of sustainable development was expected from the participants. Questions 11, 12 and 13 were asked to find out participant's future predictions. Tuba' predictions included all aspects of sustainable development. Future predictions related with people's awareness (social aspect), impacts on Kızılırmak (environmental aspect) and economic well- being (economic aspect) was derived from the quote below. As a result of the analysis she was classified in Level 3 for STS 6 *(Table 4.6)*.

> "There is still a threat for Kızılırmak. All in all, people will have to produce something to avoid poverty. So, agriculture may increase again if they [farmers in Kızılırmak] need to gain more money. On the other hand, if buffalo breeding becomes a profitable job, buffalo population will increase, and more buffalo may have negative impacts on Kızılırmak too. Nevertheless, I believe that these events [decrease in buffalo population and its results] is not a threat for future but a lesson for us. I do not believe people damaged Kızılırmak intentionally, they

just did not predict the results. People are learning with trial and error. They [people in Kızılırmak region] were not able to think the results of their actions because they never try this before. They took trainings on buffalo breeding and now they know they can make a living with this profession. Also, if there is a raising consciousness about pollution, this event may cause a gain for Kızılırmak." (Question 12)

*Table 4.6: Tuba's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environment, impacts on Kızılırmak<br>Future predictions on economy, economic well being<br>Future predictions on society, raising awareness | Level 3: Makes future predictions for three aspects of sustainable development |

#### 4.1.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

Seventh systems thinking skill investigates the ability of empathy with other people and non-human beings. Participants were expected to develop empathy with both people and non-human beings equally in the scenario. Non-human beings include all living organisms and non-living materials like soil, water or air. During the interview, she empathizes with other people by trying to explain people's reasons for engaging in agriculture and buffalo farming. However, she did not show a strong empathy with non-human beings. As a result, Tuba was classified in Level 2 for STS 7 (Table 4.7).

"The most important outcome of increasing buffalo population at Kızılırmak will be less people engaged in agriculture. Buffalo breeders learned about new buffalo products and they will gain more money. Buffalo breeding will turn into a more advantageous profession for Kızılırmak region. Because people will learn how they earn their living from buffalo breeding they will not interest in agriculture anymore." (Question 14)

*Table 4.7: Tuba's level of STS 7*

| STS | Category *(Empathy)* | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with other people | Level 2: Struggle to develop empathy with both other people and non-human beings |

#### 4.1.2.8.STS 8- Recognizing Own Responsibility in the System

Eighth systems thinking skills is about acknowledging own responsibility in the system and taking action. Participants were expected to define their role for the presented scenario. During the interviews, it is observed that Tuba shows apathy toward the environmental problems in the scenario. She is believing that she cannot find a solution by taking action on her own. In her opinion, the initial reasons for these environmental problems are rich people who waste money and resources. She thinks that because these people do not fulfill their moral obligations towards environment, so she does not have to do either. Even though she made connections with her personal life for some cases, she refused to take action in certain conditions. Details from the interview is given in the quotations below.

> "It is hard to encourage people [farmers in Kızılırmak] to change their behavior. I mean, people who give speeches on sustainability mention minimizing the carbon footprint or consuming less but they are not changing their own consumption behaviors. So, they [farmers] would ask: Why should I change my behavior? I already have less expense and waste. Why should I be the one who save the planet? There are too many rich people in the world and their consumption habits brought us here. How much my carbon footprint can affect the world?" (Question 15)

"I save money since my childhood. In addition, I am interested in ecological solutions for house cleaning since I learned how we harm nature with the chemical detergents. I am warning my mother not to use too much detergents. On the other hand, I think, if I have money I would spend it on clothing. I do not believe that people who give advice on saving world's resources or reducing consumption are practicing their own ideas." (Question 9)

Tuba's interview analysis showed that she was able to make a connection between her personal life and the scenario in a low level. However, it is observed that she strictly refuses to take responsibility about the scenario. As a result, she was classified in Level 2 for STS 8 *(Table 4.8).*

*Table 4.8: Tuba's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Making connection between issue and personal life | Level 2: Struggle to make connections between issue and personal life &taking responsibility |

#### 4.1.2.9.STS 9- Developing a Sense of Place

Ninth systems thinking skill is about participants ability to develop sense of place with different meanings attributed to a certain place. In the context of this thesis, participants were expected to define different meanings for Kızılırmak. From the interviews it can be inferred that Tuba attributed biophysical meaning to Kızılırmak which is related with its nature and political meaning related with the economic and national value of the region. Because Tuba defines Kızılırmak with including two different dimensions, she was classified in Level 2 for STS 9 *(Table 4.9).*

***About biophysical meaning:*** "Kızılırmak river represents life for me. Forget about economy, our life depends on this life source. Even the smallest reactions in our cells depend on water. Water shortages may come true in the future even if it may not seem possible now. My children may face with drought and this idea worries me. I think about what I can do to prevent this." (Question 17)

***About political meaning:*** "Kızılırmak river is a valuable source for water. It is claimed that the future wars will outbreak because of water shortages. That's why Kızılırmak is important. We need to preserve our resources." (Question 18)

*Table 4.9: Tuba's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9-Developing a sense of place | Biophysical dimension<br>Political dimension | Level 2: Defines place as including two dimensions |

### 4.1.3. Tuba's Definition of the System

All participants were asked to describe and give example to a system with the questions 19 and 20. Tuba gave her definition of the system and her example as follows:

> "System is a structure consists of several components which are in interaction with each other. In fact, the term "ecosystem" is coming from this idea. For example, in Kızılırmak ecosystem there are many components: humans, environment, animals…For example, Kızılırmak is not a solitary structure. Kızılırmak river, water, animals are part of it. These animals are in interaction, too. There are plants and humans. Humans using these components. All these are forms a system." (Question 19 & 20)

### 4.1.4. Summary for Tuba's Systems Thinking Skills

Tuba was rated in Level 3 for five systems thinking skills. In STS 1, it is observed that she concentrated on the components from environmental aspect. Additionally, she pointed out the economic aspect several times. Seven connections she found in STS 2 include components from economic aspect of sustainable development. It is observed that she can recognize the cyclic relationships in the system, found out the hidden dimensions, making future predictions on all aspects of sustainable development *(STS 4, STS 5, STS 6).* The participant portrayed a moderate rating for the systems thinking skills about developing empathy, recognizing own responsibility and developing a sense of place *(STS 7, STS 8, STS 9).* Only systems thinking skill Tuba rated in Level 1 was "the ability to make generalizations" *(STS 3).* She was not able to transfer the main idea of the scenario to other contexts with considering all aspects of sustainable development.

All in all, Tuba draws a high profile in systems thinking with reaching to Level 3 for most of the systems thinking skills. Her definition and example of system provided evidence for that she has a sensible conception about systems. Additionally, she showed that she can see a bigger picture over the given scenario with the quotation below.

> "Not only the people who live in the Kızılırmak region will be affected by this [the loss of buffalo population] also we could have affected."

*Table 4.10: Tuba's overall STS levels*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 3 |
| STS 2- Identify relationships among the system's components | 3 |
| STS 3- The ability to make generalizations | 1 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 3 |
| STS 6- Thinking temporally: Retrospection and prediction | 3 |
| STS 7- Developing an empathy with other people and non-human beings | 2 |
| STS 8- Recognizing own responsibility in the system | 2 |
| STS 9- Developing a sense of place | 2 |

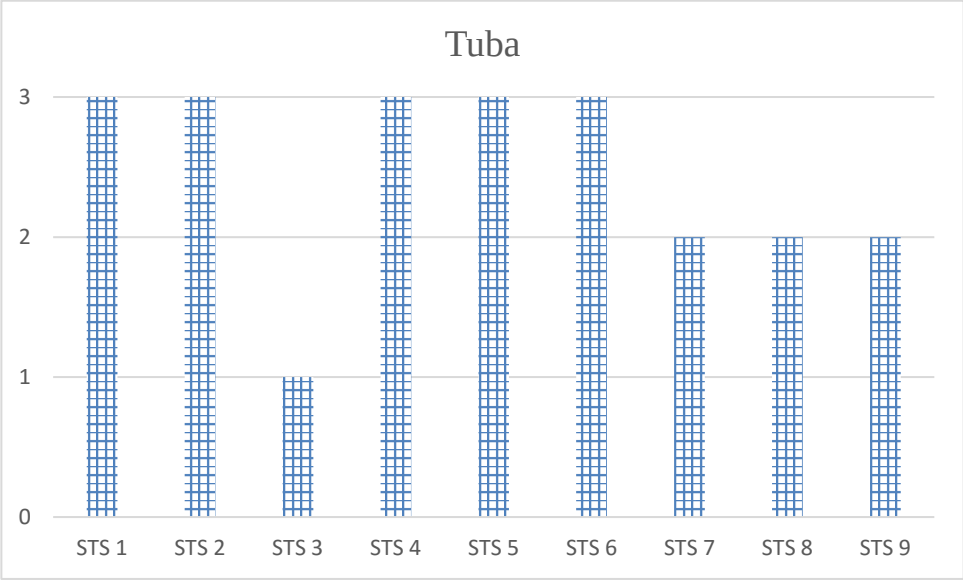


*Figure 1: Tuba's STS Levels*

## 4.2.CASE 2: EBRU

### 4.2.1. Ebru's Demographic Data

Ebru is a 25-year-old senior student from the elementary science education department of one of the well-known universities in Turkey. She was grown in a house with garden, located in a small dwelling unit outside the city center. Ebru is a member of one of the most prominent non-governmental environmental organizations of Turkey since her childhood. She donates to this organization and joins reforestation activities.

Ebru took the mandatory environmental science course of her department. Sustainability was one of the subjects discussed in the course. However, she did not hear anything about the given scenario.

### 4.2.2. Ebru's System Thinking Skills

To decide Ebru's systems thinking skills, responses of interview questions were used. For each STS findings are presented in this section.

#### 4.2.2.1.STS 1- Identify Components of a System and Processes Within the System

First STS investigates participants ability to identify components and processes in the system. Ebru was expected to find out different components and processes for every aspect of sustainable development inside the given scenario. In her answers to the interview questions 3 and 4 it is observed that she identified components and processes related to all three aspects of sustainable development.

> "Buffalos, bird species, shrubs, lakes, insect population seems very large in the area [Kızılırmak]. The text says agricultural lands are very productive. We cannot just consider the animals, there are also humans who live as a part of Kızılırmak. They are engaged in buffalo breeding and farming" (Question 3)

"Ecosystem can be keyword. Also, biodiversity, because there is a rich population. Animals, plants, lakes. Technology is used for economic efficiency. Environmental consciousness can be a keyword." (Question 4)

According to these quotations from Ebru's interview, components and processes identified by her was categorized as environmental, social, and economic *(Table 4.11).* It is seen that she was not able to state processes for any aspect of sustainable development, but she named components from all aspects of sustainable development. As a result, she was classified in Level 3 for STS 1.

*Table 4.11: Ebru's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental<br>Components: buffalos, bird species, shrubs, lakes, insect population, agricultural lands, ecosystem<br>Processes: No environmental process identified. | Social<br>Components: Humans, environmental consciousness<br>Processes: No social process identified. | Economic<br>Components: Buffalo breeding, farming, technology<br>Processes: No economic process identified. | Level 3: Identifies components and processes from all three aspects of sustainable development |

#### 4.2.2.2.STS 2- Identify Relationships Among the System's Components

Second systems thinking skill is identifying relationships between components and process. Participants were asked to name the relationships and explain the interactions they found in the scenario. Questions 5, 6 and 7 were used evaluate second systems thinking skill.

"*(chemical fertilizers and living organisms)* Chemical fertilizers not only have an impact on buffalos but also have an impact on plants, insects, all living organisms in the Kızılırmak region… *(Buffalo population and ecosystem)* Change in buffalo population can threat the balance in the ecosystem… *(Bird species- depletion of wetlands)* Kızılırmak basin is an ideal area for immigrant birds. If they deplete the wetlands this environment will change, and birds will be affected… *(Buffalo population- frogs and fishes)* If buffalo population increase, this could be an advantage for fishes and frogs because they lay their eggs in buffalo's footprints." (Question 5)

"*(Economy and ecosystem)* People in the Kızılırmak region are selling buffalo products and engaged in tourism to earn their living. Their economic wellbeing depends on the ecosystem… *(technology- environmental consciousness)* People can be using technology to raise environmental consciousness with publishing internet news about the Kızılırmak region... *(chemical fertilizers and economy*) The initial reason to use chemical fertilizers was making contribution to economy with increasing cultivation. However, at the end, chemicals had negative effects on economy… *(living organisms and Kızılırmak basin)* There are birds, plants, trees, buffalos living together on wetlands and agricultural fields of Kızılırmak… *(pesticides- ecosystem)* Pesticides damages both Kızılırmak river ecosystem and wetland ecosystem… *(agriculture- economy)* A variety of agricultural products are being harvested every year in Kızılırmak. So, agricultural fields have a connection with economy." (Question 6)

"*(natural beauty and economy)* There is a perfect nature in Kızılırmak with birds, buffalos, insects, lakes, plants… People may want to use there for touristic activities to gain more money. However, this will damage the environment, change the habitat of animals…

*(environment- environmental consciousness*) If people do not value to the natural resources and buffalos they will not do anything to fix the problems in the ecosystem. This project [mentioned in the scenario] and festivals increase awareness among people to understand the importance of buffalos and buffalo breeding." (Question 7)

Ebru found six different connections within environmental components, four connections between environmental & economic components, one connection between environmental & social components and one connection between economic & social components. On the other hand, she did not find any connections within economic components, within social components. Also, there is no connection between components from all three aspects of sustainable development. As a result, she was classified in Level 2, for STS 2. Categorization Ebru's results are presented in the Table 4.12.

*Table 4.12: Ebru's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | living organisms - Kızılırmak basin<br>buffalo population - ecosystem<br>bird species - depletion of wetlands<br>buffalo population - frogs and fishes<br>chemical fertilizers - living organisms<br>pesticides - ecosystem | Level 2: Identifies relationships among two different aspects of sustainable development (e.g. relationships between environmental – social components) |
| | Connections between social components | - | |
| | Connections between economic components | - | |
| | Connections between environmental and economic components | chemical fertilizers - economy<br>agriculture - economy<br>economy - ecosystem<br>natural beauty - economy | |
| | Connections between environmental and social components | environment - environmental consciousness | |
| | Connections between economic and social components | technology - environmental consciousness | |
| | Connections between environmental, economic and social components | - | |

#### 4.2.2.3.STS 3- The Ability to Make Generalizations

For third systems thinking skill participants were expected to implement the characteristics of the system presented in the scenario into other contexts. Participants' generalizations were categorized in terms of environmental, economic and social aspects. During the analysis of her interview, it was noticed that Ebru focused on the environmental and economic components while making generalizations:

> "I disapprove the human relationship with nature. People can do anything to increase economic efficiency, anything could be done if it makes more money. No one considers how their actions will affect nature. For example, they think that they can build shopping malls or hotels and it does not matter if they cut some trees. Most of the people think nature could compensate anything and renew itself. However, they forget that there is a limit in the nature and it have been already surpassed. When I think about this scenario about Kızılırmak I see that people are the ones who give damage the nature at the beginning. In my opinion, there are very few people have awareness and consider environment." (Question 9)

Ebru criticize the human nature relationship by discussing how economic activities harm nature. Because she did not mention any social components while making generalization, Ebru was classified in Level 3, for STS 3 (Table 4.13).

*Table 4.13: Ebru's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalizations on environmental aspect<br>Generalizations on economic aspect | Level 2: Identifies two aspects of sustainable development while making generalizations |

#### 4.2.2.4.STS 4- Understanding Hidden Dimensions of the System

Forth systems thinking skill is about finding out the hidden components of the scenario. Participants were expected to discover components related with the scenario which are not directly mentioned in the text. For Ebru's case, tourism, irrigation, health were three hidden concepts stated during the interviews. With three hidden dimensions she identified, Ebru was classified into Level 3 for STS 4 (Table 4.14).

> ***About tourism:*** "This festival [organized for drawing attraction to buffalo breeding] might be touristic too. People who are interested in local culture and foods can visit Kızılırmak with the help of festivals and contribute to the local economy as tourists." (Question 2)
>
> ***About irrigation:*** "Depredation of wetlands will cause irrigation problems in agriculture. Kızılırmak basin is a massive land. How farmers will irrigate the soil if they drain all wetlands?" (Question 11)
>
> ***About health:*** "Depredation of wetlands can cause illnesses. Farmers will continue using chemicals. Because they will eat the that food grown by chemicals farmers and their families will be affected. Toxic ingredients will accumulate in their body." (Question 12)

*Table 4.14: Ebru's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Tourism<br>Health<br>Irrigation | Level 3: Identifies three or more hidden dimensions from the scenario |

#### 4.2.2.5.STS 5- The Ability to Understand the Cyclic Nature of the Systems

Understanding cyclic nature means understanding that every component of the system is interrelated and integrated. Participants were expected to portray a cyclic relationship while examining the scenario including all three aspects of sustainable development.

Ebru's concept map drawing did not give a valid clue for her understanding of cyclic interactions. During the interview she explained a cyclic structure. However, this structure was only including environmental components. Her words on cyclic nature are quoted below. With the help of this quotation, she was classified in Level 2, for STS 5 (Table 4.15).

> "It is thought that extinction of a species in nature does not cause a risk for humans. It is often forgotten that that species is also a part of its environment. When I think about sustainability I always imagine a cycle. There are agricultural fields, buffalos, and buffalos manure used in agriculture. Organic fruits and vegetables are produced by the organic fertilizers. At the same time buffalos are eating the plants grown in the area. If one of these components, for example buffalos, are removed from this cycle this has negative effects on everything including agricultural lands, insects, humans and migration of birds." (Question 13)

*Table 4.15: Ebru's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explanation of cyclic nature of the system with environmental aspect of sustainable development. | Level 2: Explains cyclic relations in the scenario but does not includes all aspects of sustainable development. |

#### 4.2.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

For the sixth systems thinking skill participants were expected to make future predictions based on the scenario including all three aspects of sustainable development. In her responses through the interview, Ebru made several different predictions about environment, by mentioning deforestation and harming the environment; about economy by mentioning economic activities of people in the region; and society by discussing possible health problems. As a result, she was classified into Level 3 for STS 6.

> ***About economy and environment:*** "People may want to use the natural beauty of Kızılırmak for touristic activities to gain more money. They will want to build restaurants or markets over there to attract more tourists to the area. They will cut trees, spoil the vegetation. However, this will damage the environment, change the habitat of animals." (Question 7)
>
> ***About health:*** "Depredation of wetlands can cause illnesses. Farmers will continue using chemicals. Because they will eat the that food grown by chemicals farmers and their families will be affected. Toxic ingredients will accumulate in their body." (Question 12)

*Table 4.16: Ebru's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environment, impacts on environment<br>Future predictions on economy, changing economic activities<br>Future predictions on society, impacts on health | Level 3: Makes future predictions for three aspects of sustainable development |

#### 4.2.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

Seventh systems thinking skill investigated in this thesis is about participants' ability to develop empathy towards other people and non-human beings. From the answer to question 15 it is derived that Ebru can show empathy to other people [buffalo breeders] and non-human beings [buffalos] in the Kızılırmak. Accordingly, she was classified in Level 3 for STS 7 (Table 4.17).

> "If I were a buffalo breeder in Kızılırmak, I would support this project [about increasing buffalo population]. Because my job would be related with a living organism, buffalos. I would feel like I have a responsibility for their [buffalos] life because they are alive and have a right to live. If they were fed and grown by me I would endeavor to keep them alive. I would work on different projects. For example, if buffalo products do not get interest from Kızılırmak region I would try to sell them to other cities or countries. This would be a model for other buffalo breeders and increase the buffalo population." (Question 15)

*Table 4.17: Ebru's level of STS 7*

| STS | Category *(Empathy)* | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with other people<br>Empathy with non-human beings | Level 3: Considers other people's perspective and non-human beings in a complete way |

#### 4.2.2.8.STS 8- Recognizing Own Responsibility in the System

Recognizing own responsibility in the system includes taking responsibility for the changes presented in the scenario and being ready to take action about these changes. Ebru's words indicated that she understands her responsibility in the system provided in the scenario. She made a connection between her personal life and the scenario.

> "There is a connection between all components in this scenario. Sustainable development also has different components that are integrated to each other. We should direct our lives with considering sustainable development. At least we should try. Sustainable development is not only recycling. There is no advantage in recycling plastic bottles if we are using 10 different plastic bottles in a day. Using same bottle more than once is more important. Recycling is not the ultimate solution for environmental problems. Besides, not every waste can be recycled. If I need a pen, I should buy just one pen because I do not need more. Even if I throw the excess in the recycling box instead of throwing them in garbage, I am still harming nature." (Question 10)

According to this quotation above, it is derived that Ebru acknowledges her responsibility about the problems in her environment. She made connection between scenario and her personal life and affirmed that she is ready to take action. She was classified in Level 3 for STS 8 (Table 4.18).

*Table 4.18: Ebru's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Making connection between issue and personal life<br>Taking responsibility | Level 3: Makes connections between issue and personal life and takes responsibility |

#### 4.2.2.9.STS 9- Developing a Sense of Place

Last systems thinking skill in this thesis was developing a sense of place. In the context of this study, which dimensions they are considering while defining Kızılırmak was investigated. Participants were asked to define what Kızılırmak means to them and their definitions categorized in different dimensions of place.

It is observed that Ebru defines Kızılırmak in terms of biophysical and psychological dimensions. Her words about biodiversity referred to biophysical

sense of place, and about social awareness referred to psychological sense of place. As a result, she was classified in Level 2 for STS 9 (Table 4.19).

> ***About biophysical meaning:*** "I have never gone there but it seems Kızılırmak is very rich in terms of biodiversity. At first, I feel happy about that this place is not invaded by people. People did not turn there into a touristic place. Saving the nature in here is priority to people in the area. In terms of that it is a rescued zone." (Question 17)
>
> ***About psychological meaning:*** "There is not enough awareness in society about biodiversity. People's consciousness and efforts to protect this area made Kızılırmak a significant place for me." (Question 18)

*Table 4.19: Ebru's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9- Developing a sense of place | Biophysical dimension<br>Psychological dimension | Level 2: Defines place as including two dimensions |

### 4.2.3. Ebru's Definition of the System

Participants' descriptions of system were investigated with the questions 19 and 20. Ebru's definition of system portrays a connected structure, and she exemplified the system in coordination with her definition. Her words are given in the quote below.

> "A system consists of multiple components which exist together in balance. Not only livings but also non-living things can be a part of the system. For example, sometimes caves and mountains can be a home for living others…My family's house is an example to a system. We have a small garden where we grow our food and compost our organic waste, and we use this compost for growing food again. This relation is a sign of balance. We have chickens and we give them grass from the

garden. Then we use their eggs. There are a lot of components in this garden and I can see their relation." (Question 19 & 20)

### 4.2.4. Summary for Ebru's Systems Thinking Skills

Ebru was rated in Level 3 for five STS and in Level 2 for the other four STS. It is noticed that she identified far more components from environmental aspect than other two aspects of sustainable development. Accordingly, in STS 2 almost all connections she identified include a component from environmental aspect. It is also observed that even though she was able to understand the cyclic interactions in the scenario, she only discussed environment for this cycle (STS 5). On the other hand, she made future predictions considering environment, economy and society (STS 6). Additionally, she identified three hidden dimensions from the scenario (STS 4). Also, she showed a high profile for ability to develop empathy and recognizing own responsibility (STS 8). Other two STS that Ebru rated in Level 2 were about making generalizations and developing a sense of place (Table 4.20).

It can be inferred from her definition and example for system that she has a valid understanding for system. Her example for system also showed that she was able to observe a cyclic system in the nature by herself.

*Table 4.20: Ebru's overall STS levels*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 3 |
| STS 2- Identify relationships among the system's components | 2 |
| STS 3- The ability to make generalizations | 2 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 2 |
| STS 6- Thinking temporally: Retrospection and prediction | 3 |
| STS 7- Developing an empathy with other people and non-human beings | 3 |
| STS 8- Recognizing own responsibility in the system | 3 |
| STS 9- Developing a sense of place | 2 |

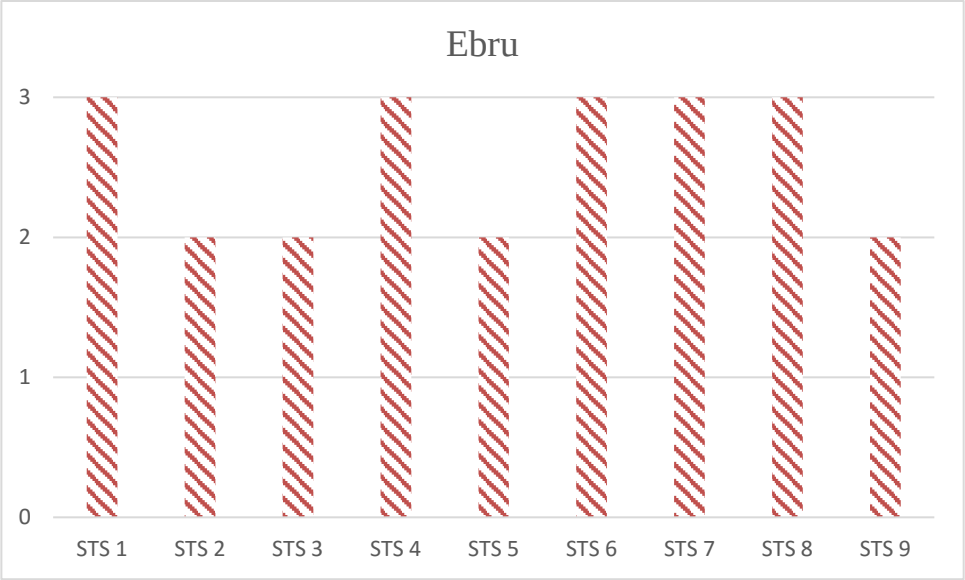


*Figure 2: Ebru's STS levels*

## 4.3.CASE 3: ASLI

### 4.3.1. Aslı's Demographic Data

Aslı is a 24-year-old senior year student from the elementary science education department of one of the prominent universities in Turkey. She has grown in a city during her childhood. She has never been a member of non-governmental organization or student group about environment or sustainability. However, she attended an environmental training workshop provided by a governmental organization.

Aslı took the mandatory environmental science course of her department which issues sustainable development during her undergraduate education. She did not hear about the event in the given scenario.

### 4.3.2. Aslı's System Thinking Skills

Aslı's responses during the interview were analyzed to understand her systems thinking skill levels. Her responses according to STS is discussed in the following section.

#### 4.3.2.1.STS 1- Identify Components of a System and Processes Within the System

The first systems thinking skill is about identifying components in the scenario from different aspects of sustainable development. Interview questions 3 and 4 was used to derive the components and processes participants identified. Aslı listed five different components for environmental aspect and four different components for social aspect of sustainable development and one component from economic aspect. She discussed human's role in terms of both social and economic aspect. In her words, humans are most vital component in this scenario:

"Components are buffalo, pesticides and human. At the beginning of this event there was only human. People's greed especially. There is nothing people cannot do for money…On the other hand there are volunteers to save the delta. They increase awareness. They admit they are harming nature" (Question 3)

"Keywords in this scenario are; chemical fertilizers, the awareness project [carried in the Kızılırmak region], festivals [organized in Kızılırmak], Kızılırmak basin, chemical fertilizers, buffalos." (Question 4)

The components identified by Aslı categorized as environmental, economic and social. There is no direct statement about economic components, but she discussed the economy in people's actions. Because she discussed human's role in the economic context. As a result, she was classified in Level 3 for STS 1 (Table 4.21).

*Table 4.21: Aslı's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental<br>Components: Buffalo, agriculture, pesticides, delta, chemical fertilizers<br>Processes: No environmental process identified. | Social<br>Components: volunteers, project, festival<br>Processes: No social process identified. | Economic<br>Components: Economy<br>Processes: No economic process identified. | Level 3: Identifies components and processes from all three aspects of sustainable development |

**4.3.2.2.STS 2- Identify Relationships Among the System's Components**

Second systems thinking skills is about participants' ability to find out relationships between different components and processes. The connections found by participants were categorized according to rubric. Aslı's answer to question 5 used for analysis of STS 2. Aslı found five different connections within environmental components, one connection between environmental & economic components, and four connections between environmental and social

components. However, there is no connection presented in Aslı's interview within social components, within economic components, between economic & social components, and between all three aspects of sustainable development. Therefore, she was classified into Level 2, for STS 2. Table 4.22 shows the classification of Aslı's findings.

> *"(living organisms and Kızılırmak basin)* Kızılırmak basin is a natural habitat for buffalos and other living organisms… *(agriculture and wetland ecosystem)* Kızılırmak basin has lakes and wetlands but the chemicals used in agriculture are changing the ecosystem in wetlands. Also, increase in agriculture means drying of wetlands that will cause problems in ecosystem… *(chemicals and buffalo population)* Use of chemicals pollute the habitat of buffalos and decrease the buffalo population... *(buffalos and other living organisms in the Kızılırmak)* Buffalos control the distribution of other animals and plants in the wetlands by providing convenient places for making nests… *(project and buffalo population)* Awareness project aims to increase buffalo population… *(wetland ecosystem and economic wellbeing)* People are earning their living from the nature of Kızılırmak. There are buffalo breeders and farmers. People's economic wellbeing is also connected with the wetland ecosystem… *(wetland ecosystem and biodiversity)* Wetland ecosystem will change due to the changes in buffalo population. This will change the biodiversity… *(biodiversity and health)* Biodiversity is necessary for human beings because there may be medicines produced from the plants in the area… *(nature and internal migration; nature and nutrition)* All changes in the Kızılırmak basin is related with the food chain. If a component is removed from this food chain, it also affects lives of the people in the area. People [in the Kızılırmak] may not supply sufficient food for themselves. They may need to migrate to other cities because the changes in the nature." (Question 6)

*Table 4.22: Aslı's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | living organisms - Kızılırmak basin agriculture - wetland ecosystem<br>buffalos - other living organisms in the Kızılırmak<br>wetland ecosystem – biodiversity<br>chemicals and buffalo population | Level 2: Identifies relationships among two different aspects of sustainable development (e.g. relationships between environmental – social components) |
| | Connections between social components | | |
| | Connections between economic components | - | |
| | Connections between environmental and economic components | wetland ecosystem - economic wellbeing | |
| | Connections between environmental and social components | project - buffalo population<br>biodiversity - health<br>nature - internal migration<br>nature - nutrition | |
| | Connections between economic and social components | - | |
| | Connections between environmental, economic and social components | - | |

#### 4.3.2.3.STS 3- The Ability to Make Generalizations

For the third systems thinking skill participants were expected to transfer their conception for the scenario to other contexts, meaning generalize the system presented in the scenario. Analysis of Aslı's interview revealed that, she includes only environmental aspect of sustainable development in her generalizations. Accordingly, she was classified in Level 1 for STS 3 (Table 4.23). She pointed out the relationship between humans and nature in her school with giving reference to the scenario.

> "As human beings we are acting selfish. We do not know the influences of our actions on the other living organisms. For example, in our school there is a large forest and as humans we are affecting the habitat of organisms who live in this forest. However, everything in nature is interrelated. Loss of a single species influence both other living organisms and people." (Question 7)

*Table 4.23: Aslı's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalization on environmental aspect | Level 1: Identifies one aspect of sustainable development while making generalizations |

#### 4.3.2.4.STS 4- Understanding Hidden Dimensions of the System

The forth systems thinking skill is about the ability to discover hidden components of a system. Participants were expected to find hidden components which are not directly mentioned in the given scenario. Throughout the Aslı's interview, she pointed out four different components which can be accepted as hidden dimensions. She claimed that raising awareness with education is one of the most important components of the scenario. The other hidden dimensions stated by Aslı were internal migration, nutrition and health, stated when she

was asked to describe the connections in the scenario. In conclusion, Aslı was classified in Level 3, for STS 4 (Table 4.24).

> ***About education:*** "School can be turned into a very productive place to raise awareness because children are open to learning. With education they can recognize why protecting the environment is important and what is the cost of destruction of natural habitats. Because children are there, and they are open to learning. In addition, children can influence their families. When they learned about protection of nature in school, they may carry this knowledge to their homes and families will learn with children, too." (Question 15)
>
> ***About health, internal migration and nutrition***: "Biodiversity is necessary for human beings because there may be medicines produced from the plants in the area…All changes in the Kızılırmak basin is related with the food chain. If a component is removed from this food chain, it also affects lives of the people in the area. People [in the Kızılırmak] may not supply sufficient food for themselves. They may need to migrate to other cities because the changes in the nature." (Question 6)

*Table 4.24: Aslı's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Migration of people<br>Food (for humans)<br>Medicine<br>Education | Level 3: Identifies three or more hidden dimensions from the scenario |

#### 4.3.2.5.STS 5- The Ability to Understand the Cyclic Nature of the Systems

Fifth systems thinking skill explores the ability to understand cyclic nature of the systems. Participants were expected to describe a cyclic relationship includes all aspects of sustainable development based on the given scenario. As

a result of the analysis of her interview it is noticed that Aslı described a cyclic relationship about the scenario. Nevertheless, the cycle she portrayed was a closed system which is not including any components from social or economic aspects. Thus, Aslı was classified in Level 2 for STS 5 (Table 4.25).

> "Everything in this scenario draws a cycle. Animals, plants, nature are all part of this cycle. They are all connected to the oxygen which is a vital component for life. However, humans are not inside this cycle. People's actions cause to break this cycle." (Question 9)

*Table 4.25: Aslı's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explanation on cyclic nature of the systems including only environment. | Level 2: Explains cyclic relations in the scenario but does not includes all aspects of sustainable development. |

#### 4.3.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

Participants were expected to propose future predictions about the scenario considering all three aspects of sustainable development for sixth systems thinking skill. Aslı's responses revealed that she can predict the future effects of the scenario. Though, her prediction was concentrated on environmental aspect. Aslı was classified into Level 1 for STS 6 (Table 4.26)

> "The issue discussed in the scenario will be threat for future because the conditions for Kızılırmak are not stable and continuous. This project may enable to increase the buffalo population but the environmental problems in Kızılırmak will not resolve immediately. Wetlands in the area were dried up. Recovering the nature can be rough." (Question 13)

*Table 4.26: Aslı's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environmental aspects | Level 1: Makes future predictions for only one aspect of sustainable development |

#### 4.3.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

Seventh systems thinking skill investigates participant's ability to empathize with other people and non-human beings. It is observed that Aslı can develop empathy with non-human beings like buffalos in the scenario. However, it is observed that she puts humans out of the cycle she draws for the scenario and blames farmers for their actions. It can be seen in her answer to question 11. Because she cannot develop empathy with other people and non-human beings at the same time Aslı was classified in Level 2 for STS 7 (Table 4.27).

> "People who organized this project [carried out in Kızılırmak] are probably buffalo breeders, but I think they were self-oriented. If they did not realize the severe impacts of decreasing buffalo population to nature it would have terrible effects. It could cause extinction of local buffalo species. Before protecting a species and its habitat people usually think that if this species is important or not. This is a selfish thought. I do not agree with this perspective. Every living creature is important." (Question 12)

*Table 4.27: Aslı's level of STS 7*

| STS | Category (Empathy) | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with non-human beings | Level 2: Struggle to develop empathy with both other people and non-human beings |

#### 4.3.2.8.STS 8- Recognizing Own Responsibility in the System

Participants were expected to recognize their role in the system presented in the scenario and take responsibility for their own actions. Aslı seemed to make a connection between her personal life and scenario. The quotation below summarizes Aslı's point of view about the scenario. As a result, she was classified in Level 3 for STS 8 (Table 4.28).

> "Education may help to achieve the environmental problems depicted in the scenario. Nevertheless, it still seems utopic to me. Even I do not give enough attention to my actions and the things I buy. I have too much stuff, but I know all the stuff I have is a responsibility for me. Even if I do not need it I can buy something just because it is cheap. There are t-shirts for 2 liras. When I think about the process, the electricity, water, labor and other resources spent to make these t-shirts I found 2 liras unreasonable." (Question 7)

*Table 4.28: Aslı's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Making connection between issue and personal life<br>Taking responsibility | Level 3: Makes connections between issue and personal life and takes responsibility |

#### 4.3.2.9.STS 9- Developing a Sense of Place

For ninth systems thinking skills participants were expected to consider Kızılırmak from different dimensions. These dimensions may include biophysical, political, psychological, or sociocultural. The questions 17 and 18 investigated the participants' sense of place. In her responses Aslı described Kızılırmak in terms of biophysical dimension by emphasizing the nature of Kızılırmak.

"I did not know that wetlands are that much important for buffalos or any other living being. I did not know pesticides and chemical fertilizers give that much harm to the nature. I realized the importance of Kızılırmak. …For example, there is a bird paradise in Kızılırmak and lots of bird species. Decrease in the population of these species effects all ecosystem. (Question 17 & 18)

*Table 4.29: Aslı's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9- Developing a sense of place | Biophysical dimension | Level 1: Defines place as including one dimension |

### 4.3.3. Aslı's Definition of the System

In order to understand the conceptions about systems participants were asked to define and exemplify system. Aslı gave a simple definition for the system and a detailed example.

"I define the system as a cycle which has different components. Everything is interconnected in this cycle. There is an input, a process and an output. …When I think about systems, education system comes to my mind because it has an input, process and output. Input is the child. The education she takes in the school is the process. There are the components of the school which are the books, friends, and style of her teacher. Output is the child's personality. She starts working and the cycle begins again. The components of these systems are affecting each other of course. For example, the child is coming from a family with bad financial situation, does not have a cultural background, but school gives her social mobility. So, process is affecting the input." (Question 19 & 20)

### 4.3.4. Summary for Aslı's Systems Thinking Skills

In conclusion, Aslı was reached at Level 3 for three systems thinking skills. It is observed that she is concentrated on the components from environmental aspect more than the other two aspects of sustainable development for STS 1, but she was able to identify components from them too. Other two STSs that she rated in Level 3 was understanding hidden dimensions and recognizing own responsibility *(STS 4, STS 8).* She showed a strong personal interaction with the scenario. Aslı was not able to reach at the highest rank in identifying relationships within the system, recognizing the cyclic nature of the system and developing empathy *(STS 2, STS 5, STS 7)*. All connections she found in STS 2 were including a component from environmental aspect. Moreover, she concentrated on environment in the three STSs she rated in Level 1 *(STS 3, STS 6, STS 9).* Lastly, in her systems definition she gave a valid definition for system, but she did not exemplify a natural system. Instead, she showed a systemic relation in education meaning that she did not considers systems in natural cycles. Aslı's overall levels for STS is presented in Table 4.30.

*Table 4.30: Aslı's overall levels of STS*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 3 |
| STS 2- Identify relationships among the system's components | 2 |
| STS 3- The ability to make generalizations | 1 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 2 |
| STS 6- Thinking temporally: Retrospection and prediction | 1 |
| STS 7- Developing an empathy with other people and non-human beings | 2 |
| STS 8- Recognizing own responsibility in the system | 3 |
| STS 9- Developing a sense of place | 1 |

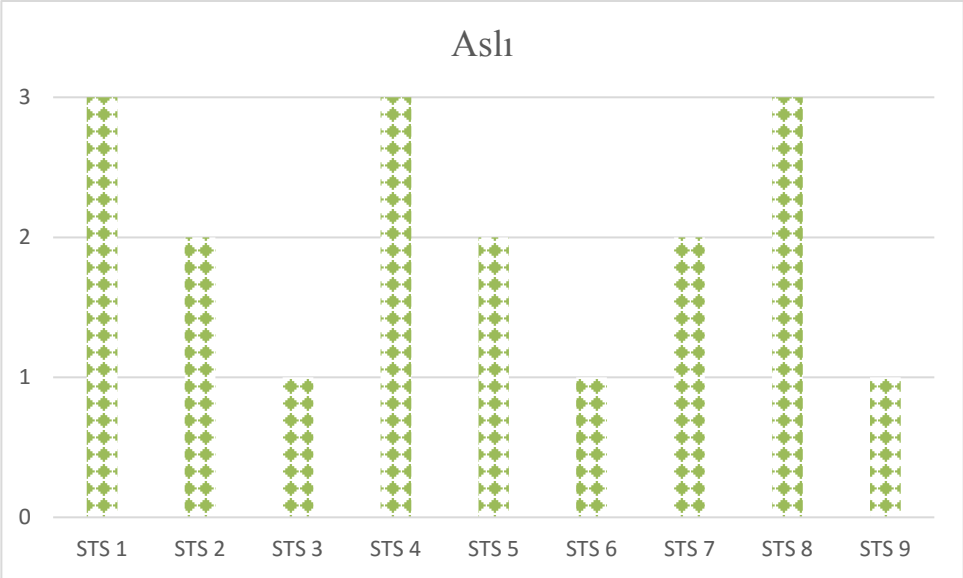


*Figure 3: Aslı's STS levels*

## 4.4.CASE 4: BURCU

### 4.4.1. Burcu's Demographic Data

Burcu is a 23-year-old senior student from the elementary science education department of one of the well-known universities in Turkey. She spent her childhood in a small town. Even though she is interested in environment, she has never been a member of a non-governmental organization or student group about environment.

The only course related with environment and sustainability she took during her undergraduate education is the mandatory environmental sciences course, which discusses sustainability as a part of its curriculum. Also, she did not hear the scenario before.

### 4.4.2. Burcu's System Thinking Skills

Nine systems thinking skills presented in this thesis was evaluated with using the interviews and the rubric developed for this thesis. Findings of the analysis of Burcu's interview is presented in this section, separated for each STS.

#### 4.4.2.1.STS 1- Identify Components of a System and Processes Within the System

Identifying components and processes was the first systems thinking skill in this thesis. Participants were expected to list different components and processes from different aspects of sustainable development. Questions 3 and 4 were used to collect evidence for the first systems thinking skill. Burcu listed seven components and two processes related with environmental and one component from social aspect of sustainable development. On the other hand, there was no component related with economic aspect (Table 4.31). Thus, she was classified in Level 2 for STS 1.

"The components of this scenario are biodiversity, ecology, natural balance, Kızılırmak basin, living organisms, chemical fertilizers, and pesticides. Then there are changes like habitat destruction, decrease in buffalo population and project to increase social awareness… Keywords in this scenario are; importance of biodiversity, food chain, protection of Kızılırmak basin." (Question 3 & 4)

*Table 4.31: Burcu's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental<br>Components: biodiversity, ecology, natural balance, Kızılırmak basin, living organisms, chemical fertilizers, pesticides<br>Processes: habitat destruction, decrease in buffalo population | Social<br>Components: project<br>Processes: No social process identified. | Economic<br>Components: No economic component identified.<br>Processes: No economic process identified. | Level 2: Identifies components and processes from two aspects of sustainable development |

#### 4.4.2.2. STS 2- Identify Relationships Among the System's Components

The second systems thinking skill is about the relationships within different components and processes. Participants were expected to find out connections between different components of the system presented in the scenario. Burcu stated seven different connections within environmental components, three different connections between environmental & economic components, one connection between economic and social components and one connection between environmental and social components. Nevertheless, no relationship found in Burcu's interview within social components, within economic

components and between all three aspects of sustainable development (Table 4.32). Burcu was classified into Level 2, for STS 2.

> "*(insects and birds)* The scenario tells that there is a diverse insect population in the Kızılırmak basin. Birds are feeding with this insects and Kızılırmak becomes a fruitful habitat for birds… *(pesticides and insects)* However, pesticides cause decrease in insect population… *(chemical fertilizers and plants)* There is a rich plant population in the area but because of chemical fertilizers these plants are damaged… *(buffalo population and project)* People needed to recover the habitat in Kızılırmak, so they organized a social project to increase the buffalo population… *(nature of Kızılırmak and economic wellbeing)* There is also an economic component; professions like fishing and buffalo breeding. People engaged in these professions depend on the nature to make their living. When the nature of the Kızılırmak was damaged also economic wellbeing of people [in the Kızılırmak] was damaged… *(buffalo population and biodiversity)* Buffalos are controlling the distribution of plants and other animals. Thus, when the buffalo population decrease it also damages the biodiversity in the area… *(buffalo population and wetlands)* Buffalos are living in the wetlands. With pollution of wetlands by chemical fertilizers buffalo population started to decrease. When there are less buffalo in the are people… *(agriculture and biodiversity)* When people turned wetlands into agricultural fields lots of species who live in the Kızılırmak affected. Most of the plant layer and grassland was lost in the area." (Question 5)

> "*(decrease in buffalo population and economy)* Chemical fertilizers and pesticides polluted the wetlands and make there unable to live for buffalos. Consequently, buffalos and wetlands lost their economic value for buffalo breeders and more people were started to engage in agriculture… *(awareness project and economy)* An awareness project

and a festival organized in the area to draw attention to buffalo farming and raise the economic value of buffalos. New technology for buffalo breeding and new buffalo products promoted with these activities… *(chemical fertilizers and biodiversity)* Chemicals pollute wetlands and destroy habitats of species who live there like fishes, insects, birds, plants… *(ecologic balance and buffalo breeding)* The problems in the ecosystem tried to be solved by supporting buffalo farming. Buffalo breeding provides an alternative economic source for farming [agriculture]. By this way, an ecologic balance could be established in Kızılırmak." (Question 6)

*Table 4.32: Burcu's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | pesticides - insects<br>insects - birds<br>chemical fertilizers - plants<br>buffalo population - wetlands<br>agriculture - biodiversity<br>chemical fertilizers - biodiversity<br>buffalo population - biodiversity | Level 2: Identifies relationships among two different aspects of sustainable development (relationships between economic – social components) |
| | Connections between social components | - | |
| | Connections between economic components | - | |
| | Connections between environmental and economic components | nature of Kızılırmak - economic wellbeing<br>decrease in buffalo population - economy<br>ecologic balance - buffalo breeding | |
| | Connections between environmental and social components | buffalo population - project | |
| | Connections between economic and social components | awareness project - economy | |
| | Connections between environmental, economic and social components | - | |

#### 4.4.2.3.STS 3- The Ability to Make Generalizations

Ability to make generalizations was the third systems thinking skill in this study. This skill evaluates the participant's ability to discuss their conceptions of the present scenario into another context with considering environmental, economic and social. According to the interviews, Burcu was able to generalize the scenario from the environmental and economic perspective. Therefore, she was classified in Level 2 for STS 3 (Table 4.33)

> "As it is also seen in this scenario people do not know how natural cycles work. We [as human beings] should learn more about nature. Only students majored in biology have detailed information about ecology. However, all people should know their place and effects on nature. When we do not know the relationship between us and other living organisms like animals and plants, their life may seem worthless. On the contrary, even a small ant has a unique place in the nature. Because people do not acknowledge natural connections they just consider economic efficiency while changing a component in nature." (Question 9)

*Table 4.33: Burcu's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalizations on environmental aspect<br>Generalizations on economic aspect | Level 2: Identifies two aspects of sustainable development while making generalizations |

#### 4.4.2.4.STS 4- Understanding Hidden Dimensions of the System

Fourth systems thinking skills was about finding out the hidden dimensions in the scenario. These hidden dimensions can be components that are not specifically pointed out in the text. For example, even though sustainable development was not directly stated, Burcu listed this concept as one of the components of the scenario in the fourth question. In addition, she proposed sustainable development as a solution to the problems in the Kızılırmak area.

> ***About sustainable development:*** "If I design a project to solve the problems in the Kızılırmak basin, first I would express the meaning of sustainable development, and why it is important to adopt this concept to our lives. Pesticides, buffalos, local products, and animals are all necessary components of Kızılırmak, and they can be considered as a whole, in terms of sustainable development." (Question 16)

In addition, Burcu mentioned ecologic balance and health which can be considered as hidden dimensions. In one of her responses, she connected ecological balance and health:

> ***About ecological balance and health:*** "If there are more and more agricultural fields in Kızılırmak, there is less place to live for living beings. This will disturb the ecologic balance…May be farmers will harvest more crops at the end and improve their economic wellbeing. However, the products will be full of toxic chemicals and impair people's health." (Question 11)

In total, Burcu listed three component as hidden dimensions, which are, sustainable development, ecological balance and health. As a result, she was classified into Level 3, for STS 4 (Table 4.34).

*Table 4.34: Burcu's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Sustainable development<br>Ecologic balance<br>Health | Level 3: Identifies three or more hidden dimensions from the scenario |

#### 4.4.2.5.STS 5- The Ability to Understand the Cyclic Nature of the Systems

The fifth systems thinking skill in this thesis was about recognizing the cyclic relationships in the system. Participants were expected to find cyclic relationships between different aspects of sustainable development.

In one of her answers Burcu portrayed a cyclic relationship between environmental *(ecological balance)*, economic *(economic wellbeing)* and social *(health)* components from the scenario. Thus, she was classified in Level 3 for STS 5 (Table 4.35).

> "If there are more and more agricultural fields in Kızılırmak, there is less place to live for living beings. People will take away their habitats. This will disturb the ecologic balance. There will be more environmental pollution due to pesticides and chemicals used for agriculture. As a result, insects will be lost. Then birds will be affected and leave the Kızılırmak region. Correlatively, plants and other livings will be harmed. May be farmers will harvest more crops at the end and improve their economic wellbeing. However, the products will be full of toxic chemicals and impair people's health." (Question 11)

*Table 4.35: Burcu's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explanation on cyclic nature of the systems including environment, economy and society. | Level 3: Explains "cyclic" relations in the scenario and contains three aspects (environment, economy, society) |

#### 4.4.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

Understanding the present actions will have future effects and making predictions about these effects was the main idea of the sixth systems thinking skill. In her interview, Burcu proposed future predictions about ecologic balance and public health.

> "Chemicals used in agriculture impact both nature and people. It will cause biodiversity loss around Kızılırmak in the future. There may be lost species which have not even recorded. It is not about losing only one species, others connected to them in the food chain will also be affected. On the other hand, chemicals also toxify water, soil, air. This will affect public health and can cause illnesses in the future." (Question 12)

The quotation above portrays Burcu's future predictions on environment and society, but economy aspect of sustainable development was not seen among her answers. Therefore, she was classified into Level 2 for STS 6 (Table 4.36).

*Table 4.36: Burcu's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environmental aspects<br>Future predictions on social aspects | Level 2: Makes future predictions for two aspects of sustainable development |

#### 4.4.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

The seventh systems thinking skills considers participants ability to develop empathy with other people and non-human beings. As a result of the interview analysis it is observed that, Burcu shows empathy towards both other people and non-human beings in the scenario.

> ***Empathy towards non-human beings:*** "If there are more and more agricultural fields in Kızılırmak, there is less place to live for living beings. People will take away their habitats. This will disturb the ecologic balance." (Question 11)

> ***Empathy towards other people:*** "If I design a project to solve the problems in the Kızılırmak basin, first I would express the meaning of sustainable development, and why it is important to adopt this concept to our lives… I would make a comparison between sustainable agriculture, buffalo breeding and using chemicals instead of directly telling chemicals are dangerous. I would show them they can make money without harming nature with chemicals. Otherwise people may react to the new techniques because they are earning their living from agriculture and buffalo breeding." (Question 16)

By mentioning the importance of natural habitats for animals Burcu showed that she can empathize with non-human beings and by

mentioning farmers' economic concerns she showed that she can empathize with other people. Accordingly, she was classified into Level 3 for STS 7.

*Table 4.37: Burcu's level of STS 7*

| STS | Category *(Empathy)* | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with other people<br>Empathy with non-human beings | Level 3: Considers other people's perspective and non-human beings in a complete way |

#### 4.4.2.8.STS 8- Recognizing Own Responsibility in the System

The eight systems thinking skill discussed in this thesis was recognizing own responsibility. Participants were expected to make a connection between the issue and her personal life and takes responsibility for their actions. In her response to the question 17, Burcu made a connection between the scenario and her personal life. However, she did not define a responsibility for herself about the scenario. Thus, Burcu was classified in Level 2 for STS 8 (Table 4.38).

> "As human beings we are also part of the food chain in the nature. Therefore, the imbalance in the nature of Kızılırmak will affect me. For example, I will eat these crops produced with chemicals. They will affect my health." (Question 17)

*Table 4.38: Burcu's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Making connection between issue and personal life | Level 2: Struggle to make connections between issue and personal life & taking responsibility |

#### 4.4.2.9.STS 9- Developing a Sense of Place

Developing a sense of place means understanding different dimensions of a place, for this thesis, Kızılırmak basin. Participants were expected to acknowledge biophysical, political, psychological and sociocultural meanings of Kızılırmak basin. During the interview Burcu only defined biophysical meaning of Kızılırmak. Therefore, she was classified in Level 1 for STS 9 (Table 4.39).

> "I did not know anything about Kızılırmak before, I realized its importance now. It is a habitat for lots of different species. It is a unique place for the living creatures. Kızılırmak is an important place for me because of this wide biodiversity." (Question 18)

*Table 4.39: Burcu's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9- Developing a sense of place | Biophysical dimension | Level 1: Defines place as including one dimension |

### 4.4.3. Burcu's Definition of the System

In questions 19 and 20 participants were asked to define and exemplify the system in order to understand their conceptions on system. Burcu defined system with its relationships and explained ecosystem as an example.

> "A system has its own components. The relationships between these components form the system itself… For example, consider an ecosystem. There are little systems that form the ecosystem, like water system, soil system, air system… There are interactions between these little systems. Also, there are processes inside them. When a disconnection occurs between these components, the continuity of the system is interrupted. (Question 19 & 20)

### 4.4.4. Summary for Burcu's Systems Thinking Skills

All in all, for three systems thinking skills Burcu was rated in Level 3 *(STS 4, STS 5, STS 7)*. On the other hand, for five systems thinking skills she was rated in Level 2 *(STS 1, STS 2, STS 3, STS 6, STS 8).* Ability to find components and processes within the systems (STS 1) was one of them. Burcu was the only participant who did not identify any component or processes from the economic aspect of sustainable development while naming the components of the scenario. It is observed that she is concentrated in environmental components by far. Accordingly, most of the connections she found were the ones within environmental components (STS 2). Even though, she achieved to find out connections within different aspects of sustainable development, they were mostly in between environment and other aspects. The only systems thinking skill Burcu was rated in Level 1 was the STS 9, developing a sense of place. She defined only biophysical meaning for Kızılırmak basin. Lastly, it is observed that Burcu's system definition was simple but accurate. Also, from her example to system it is understood that she was able to recognize that systems components can be systems, too. Her overall STS scores are presented in Table 4.40.

*Table 4.40: Burcu's overall STS levels*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 2 |
| STS 2- Identify relationships among the system's components | 2 |
| STS 3- The ability to make generalizations | 2 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 3 |
| STS 6- Thinking temporally: Retrospection and prediction | 2 |
| STS 7- Developing an empathy with other people and non-human beings | 3 |
| STS 8- Recognizing own responsibility in the system | 2 |
| STS 9- Developing a sense of place | 1 |

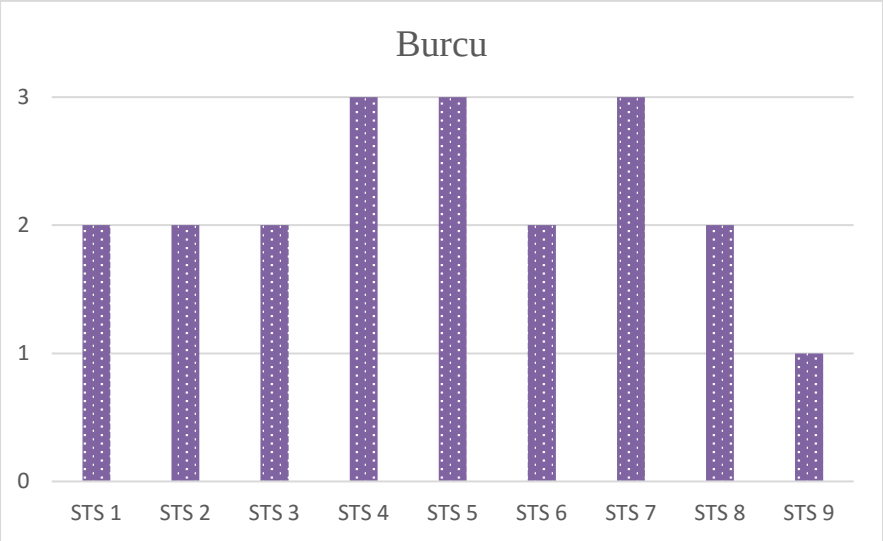


*Figure 4: Burcu's STS levels*

## 4.5.CASE 5: YAPRAK

### 4.5.1. Yaprak's Demographic Data

Yaprak, is a 23-year-old senior student from the elementary science education department of one of the well-known universities in Turkey. She spent her childhood in a small region of a big city. She has never joined a non-governmental organization or student group about environment or sustainable development, but she stated that she is interested in being part of a community about environment and she is interested in recycling. She attended garbage collection activities at the spring festival of her university.

Yaprak took mandatory environmental sciences course of her department. Additionally, she took an elective course on education and sustainability. She did not hear the scenario before.

### 4.5.2. Yaprak's System Thinking Skills

Yaprak's level for each systems thinking skill was analyzed by using her interview and the rubric developed in this thesis. Analysis for each systems thinking skill is presented in this section.

#### 4.5.2.1.STS 1- Identify Components of a System and Processes Within the System

Answers of questions 3 and 4 in the interview were used to analyze STS 1. Yaprak found out 9 different components and processes from environmental aspect, two different components from social aspect and four different components from economic aspect of sustainable development (Table 4.41). Even though environmental components are predominating in her case, because she identified components from all aspects of sustainable development, she was classified in Level 3 for STS 1.

"The components of this scenario are human, agriculture, economy, ecosystem, animals, biodiversity, geography… Biodiversity, economy, economic development, economic efficiency in the use of natural sources, education, interactions within species can be keywords for this scenario. Expanding agricultural fields, chemical fertilizers, sources of living, natural habitats can also be listed as keywords." (Question 3 & 4)

*Table 4.41: Yaprak's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental | Social | Economic | Level 3: Identifies components and processes from all three aspects of sustainable development |
| | Components: agriculture, ecosystem, animals, biodiversity, geography, chemical fertilizers, natural habitats<br>Processes: expanding agricultural fields, interactions within species | Components: human, education<br>Processes: No social process identified. | Components: economy, economic development, economic efficiency, sources of living<br>Processes: No economic process identified. | |

#### 4.5.2.2.STS 2- Identify Relationships Among the System's Components

Yaprak stated 9 connections within environmental components, one connection within social components and two connections within economic components and three connections between environmental & economic components. On the other hand, there was no connection between environmental and social components, between economic & social components and between all three aspects of sustainable development is not observed in Yaprak's responses (Table 4.42). Based on this evidence, she was classified into Level 2, for STS 2.

> "*(buffalo population and chemical fertilizers)* Buffalos are spending too much time in water but water sources around Kızılırmak were polluted because of chemical fertilizers. This is one of the reasons of decrease in buffalo population… *(depletion of wetlands and biodiversity)* Depletion of wetlands not only affects buffalos but also affects other livings in the area. Fishes, plants, birds can be impacted… *(sale of buffalo products and buffalo population)* With the awareness project people living in the Kızılırmak region learned to produce new buffalo products. This will impact the buffalo population… *(patent rights- buffalo breeding)* Buffalo breeders' cooperative got patent rights for new buffalo products. This fact may encourage people to engage in buffalo breeding." (Question 5)

> "*(plants and birds)* Plants provide shelter for birds… *(birds and fishes)* Plants use fishes as a food source… *(plants and buffalos)* Buffalos use plants as a food source… *(wetlands and buffalos)* Wetlands are the natural habitat of buffalos… *(buffalos and buffalo breeding)* People are related to buffalos with economic reasons. They are earning their living from

buffalo breeding… *(pesticides and biodiversity)* Pesticides are damaging the ecosystem and have negative impacts on biodiversity… *(wetlands and birds)* Wetlands provide shelter and food for birds… *(biodiversity and economy)* If biodiversity is preserved people can retain their economic activities… *(public awareness and education)* There is a need for public awareness to preserve ecosystem. Education is the solution to develop an awareness… *(biodiversity and economy)* When buffalo breeding provided more money people in the Kızılırmak region started to protect buffalos. If people need a species for economic growth they preserve it… *(technology and economy)* Technology provided an economic source for people. They started to produce new and high-quality products. Also new sales channels formed by using technology." (Question 6)

"*(geography and biodiversity)* Geography affects biodiversity. Existence of wetlands, the physical structure of the land, productivity of soil affects the plant and animal species… *(economy and biodiversity)* People's economic activities impact other living species. For example, fishing may cause decreasing of fish population or agriculture may impact other livings in the area." (Question 7)

*Table 4.42: Yaprak's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | buffalo population - chemical fertilizers<br>depletion of wetlands - biodiversity<br>plants - birds<br>birds - fishes<br>plants - buffalos<br>geography - biodiversity<br>wetlands - buffalos<br>pesticides - biodiversity<br>wetlands - birds | Level 2: Identifies relationships among two different aspects of sustainable development (e.g. relationships between environmental – social components) |
| | Connections between social components | public awareness - education | |
| | Connections between economic components | patent rights - buffalo breeding<br>technology - economy | |
| | Connections between environmental and economic components | sale of buffalo products - buffalo population<br>buffalos - buffalo breeding<br>biodiversity - economy | |
| | Connections between environmental and social components | - | |
| | Connections between economic and social components | - | |
| | Connections between environmental, economic and social components | - | |

#### 4.5.2.3.STS 3- The Ability to Make Generalizations

In her responses to the interview, Yaprak pointed out a generalization including economy and environmental aspect. She drew attention to the relationship within agricultural production, economy and climate change in other regions of Turkey. As a result, Yaprak was classified into Level 2, for STS 3 (Table 4.43).

> "In order to establish sustainable development, it is necessary to protect natural habitats for other species. For example, there is sunflower production in Trakya region of Turkey. However, because of the effects of climate change profitability of the farming is decreasing. Changing in natural variables influences economy. To obtain a sustainable system protection of nature is critical." (Question 10)

*Table 4.43: Yaprak's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalizations on environmental aspect<br>Generalizations on economic aspect | Level 2: Identifies two aspects of sustainable development while making generalizations |

#### 4.5.2.4.STS 4- Understanding Hidden Dimensions of the System

Throughout the interview, Yaprak stated five hidden dimensions which are geography, education, sustainability, climate change and internal migration. As a result, she was classified in Level 3 for STS 4 (Table 4.44). Yaprak named sustainability as one of the components in the scenario. For other hidden dimensions, quotations were given below.

> ***About geography:*** "Geography affects biodiversity. Existence of wetlands, the physical structure of the land, productivity of soil affects the plant and animal species" (Question 7)

> ***About education:*** "There is a need for public awareness to preserve ecosystem. Education is the solution to develop an awareness." (Question 6)

***About internal migration:*** "People who live in the Kızılırmak region might want to move to bigger cities to work on different jobs. They might want to gain more money. This could be the initial reason for decreasing popularity of buffalo breeding." (Question 14)

***About climate change:*** "…Because of the effects of climate change profitability of the farming is decreasing." (Question 10)

*Table 4.44: Yaprak's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Geography<br>Education<br>Sustainability<br>Climate change<br>Migration | Level 3: Identifies three or more hidden dimensions from the scenario |

**4.5.2.5.STS 5- The Ability to Understand the Cyclic Nature of the Systems**

In her concept map Yaprak, connected almost all components to each other. She explained that all the components in the concept map are influencing each other and commented about these interactions. This evidence provided the clue for Yaprak's ability to understand cyclic nature in the scenario with all aspects of sustainable development in these responses. Therefore, she was classified into Level 3 for STS 5 (Table 4.45).

"Interferences to the ecosystem will have harmful effects to both nature and humans. First of all, the plants and animals that people feed will decrease because we (as humans) are changing their habitats. The balance in the nature is already breaking down because of us, there is climate change, melting of glaciers… If I were living in Kızılırmak and fed with these buffalo products the problems in this scenario may influence my life, too, in terms of health and economy. Besides the ecosystem will be damaged and all livings will be affected." (Question 12)

*Table 4.45: Yaprak's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explains cyclic nature of the system considering all aspects of sustainable development. | Level 3: Explains "cyclic" relations in the scenario and contains three aspects (environment, economy, society) |

#### 4.5.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

The quotation given in 4.5.2.5., also includes Yaprak's predictions on the scenario. By mentioning nature, economy and health issues in her response Yaprak presented the possible future outcomes of the text in her opinion. Because components from all aspects of the scenario were discussed she was classified into Level 3 for STS 6 (Table 4.46).

*Table 4.46: Yaprak's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environmental aspects<br>Future predictions on economic aspects<br>Future predictions on social aspects | Level 3: Makes future predictions for three aspects of sustainable development |

#### 4.5.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

Yaprak showed that she can empathize with other people by explaining the reasons of decreasing buffalo population in the perspective of buffalo breeders. Also, she criticized the industrial farming in the animals' point of view, which gave evidence for her empathy towards non-human beings. Based on her answers quoted below, she was classified into Level 3 for STS 7 (Table 4.47).

"People who live in the Kızılırmak region might want to move to bigger cities to work on different jobs. They might want to gain more money. This could be the initial reason for decreasing popularity of buffalo breeding. Buffalo breeding requires hard work but not give too much money. It does not seem like an easy profession." (Question 14)

"Unconscious interventions to nature like overhunting and factory farming have negative effects on animals and plants. There is no freedom for animals in the factories. They need to live in the wilderness, in the wetlands. People should not have right to decide whether they can live or not." (Question 7)

*Table 4.47: Yaprak's level of STS 7*

| STS | Category *(Empathy)* | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with other people<br>Empathy with non-human beings | Level 3: Considers other people's perspective and non-human beings in a complete way |

**4.5.2.8.STS 8- Recognizing Own Responsibility in The System**

Yaprak pointed out that her personal experiences. It is observed that she can relate the scenario with her personal life. Also, she defined a responsibility for herself while reasoning about the scenario. Thus, she was classified into Level 3 for STS 8 (Table 4.48).

"There were cattle and chickens around the place I grew up, but now there are not because of urbanization. Even a road construction damages the habitats of other species." (Question 10)

"People can live with less. We are exaggerating our expanses. If all houses have a garden everyone can grow their own food and can exchange their crops with each other. This will help to protect nature." (Question 9)

*Table 4.48: Yaprak's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Making connection between issue and personal life<br>Taking responsibility | Level 3: Makes connections between issue and personal life and takes responsibility |

#### 4.5.2.9.STS 9- Developing a Sense of Place

When she was asked to talk about the meaning of Kızılırmak to her, Yaprak described biophysical dimension of the place. This description classified her into Level 1 for STS 9 (Table 4.49).

> "Kızılırmak basin consists of lots of lakes, wetlands and variety of species. Having this variety of natural components in a place is crucial in my opinion. It is necessary to protect this land to have natural balance. This rich environment supports life of humans, animals and plants." (Question 18)

*Table 4.49: Yaprak's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9- Developing a sense of place | Biophysical dimension | Level 1: Defines place as including one dimension |

### 4.5.3. Yaprak's Definition of the System

Yaprak's described system as a structure composed of interacting processes and gave education system as an example. Her description and example are given in the quote below.

> "A system is a continuously working structure which has a process, interactions... For example, education system. There are people, curriculum, schools and buildings, teachers, students, managers, and ministry of education in this system. They are all connected and

responsible from each other. They are all works in an order. Simply, there is a curriculum, teacher is influenced by this curriculum and as a result, children are raised with this curriculum." (Question 19 & 20)

### 4.5.4. Summary for Yaprak's Systems Thinking Skills

In conclusion, Yaprak drew a high profile in systems thinking. She was rated in Level 3 for six systems thinking skills *(STS 1, STS 4, STS 5, STS 6, STS 7 and STS 8)*, and Level 2 for two systems thinking skills *(STS 2 and STS 3).* The only systems thinking skill she was rated in the lowest level was "developing a sense of place" *(STS 9)*. It was observed that she was concentrated in the biophysical dimension of place, like other participants. Additionally, it was observed that she had a concrete definition for system. She explained system of education as example of system, like Aslı.

*Table 4.50: Yaprak's overall STS levels*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 3 |
| STS 2- Identify relationships among the system's components | 2 |
| STS 3- The ability to make generalizations | 2 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 3 |
| STS 6- Thinking temporally: Retrospection and prediction | 3 |
| STS 7- Developing an empathy with other people and non-human beings | 3 |
| STS 8- Recognizing own responsibility in the system | 3 |
| STS 9- Developing a sense of place | 1 |

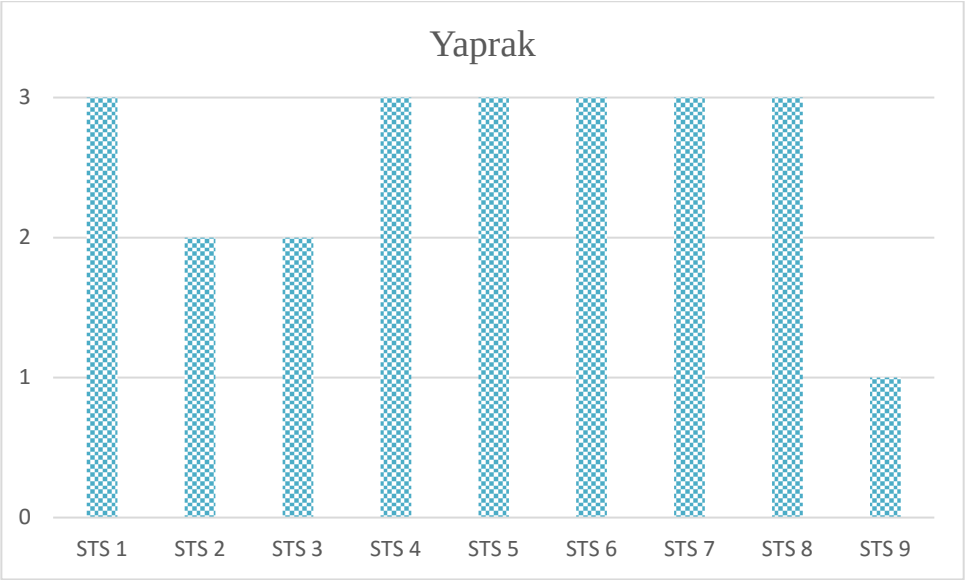


*Figure 5: Yaprak's STS levels*

## 4.6.CASE 6: DENİZ

### 4.6.1. Deniz's Demographic Data

Deniz is a 23-year-old forth year student from the elementary science education department of one of the well-known universities in Turkey. She was grown in a small village. She has never been a member of any non-governmental organization or student group about environment. However, she attended a tree planting event.

She took the environmental science course of her department which issues sustainability in its context, but she did not hear the scenario before participating in this study.

### 4.6.2. Deniz's System Thinking Skills

Interviews were analyzed by using the rubric developed for this study. Findings for each systems thinking skill and Deniz's levels of STS is presented in the present section.

#### 4.6.2.1.STS 1- Identify Components of a System and Processes Within the System

Deniz listed 8 different components from environmental aspect and two different components from economic aspect of sustainable development. However, she did not identify any component from social aspect. Therefore, she was classified into Level 2 for STS 1 (Table 4.51).

> "Chemicals, plants and animals can be components of this case… The keywords in this scenario are population of species, drought, loss of biodiversity, loss of economic value of products, technology, chemical fertilizers, pesticides, nature, and agriculture." (Questions 3 & 4)

*Table 4.51: Deniz's level of STS 1*

| STS | Category *(Components and Processes)* | | | Level |
|---|---|---|---|---|
| STS 1- Identify components of a system and processes within the system | Environmental<br>Components: plants, animals, drought, chemical fertilizers, pesticides, nature, agriculture<br>Processes: loss of biodiversity | Social<br>Components: No social component identified.<br>Processes: No social process identified. | Economic<br>Components: technology<br>Processes: loss of economic value of products | Level 2: Identifies components and processes from two aspects of sustainable development |

#### 4.6.2.2.STS 2- Identify Relationships Among the System's Components

Deniz identified five different connections within environmental components, one different connections within economic components and two different connections between environmental and economic components. In contrast, she did not state any connections within social components, between environmental and social components, between economic and social components and all three aspects of sustainable development. Therefore, she was classified into Level 2 for STS 2.

> "*(birds and insects)* Immigrant birds come to Kızılırmak from all over the worlds and rest in there. Insects of the delta are the food source for these birds… *(buffalo population and other living organisms)* Buffalos are affecting the population of other animals and plants… *(buffalos and economy)* Buffalo products hold an economic value for people in the region. They earn their living from buffalos… *(agriculture and biodiversity)* Agricultural fields are damaging the natural habitats for most of the species and cause biodiversity loss." (Question 5)

> "*(chemicals and biodiversity)* Chemicals used in agriculture cause drought and toxifying productive soil. This affects plants and animals living in the Kızılırmak basin… *(chemicals and economy)* Losing

productive agricultural fields because of chemicals cause economic loss for people… *(wetlands and biodiversity)* Wetlands are important for most of the species in the area. Water is a vital source for life… *(local economy and national economy)* With encouraging buffalo breeding there is an attempt to improve local economy. There is an economic development in the Kızılırmak region. On the other hand, improvements in local economy will also lead to improvements in national economy because all country will use the products produces in the Kızılırmak." (Question 6)

*Table 4.52: Deniz's level of STS 2*

| STS | Category (Connections) | | Level |
|---|---|---|---|
| STS 2- Identify relationships among the system's components | Connections between environmental components | birds - insects<br>buffalo population - other living organisms<br>agriculture - biodiversity<br>chemicals - biodiversity<br>wetlands - biodiversity | Level 2: Identifies relationships among two different aspects of sustainable development (e.g. relationships between environmental – social components) |
| | Connections between social components | - | |
| | Connections between economic components | local economy - national economy | |
| | Connections between environmental and economic components | buffalos - economy<br>chemicals - economy | |
| | Connections between environmental and social components | - | |
| | Connections between economic and social components | - | |
| | Connections between environmental, economic and social components | - | |

#### 4.6.2.3.STS 3- The Ability to Make Generalizations

In terms of generalizations Deniz's interview has weak clues. It cannot be claimed that she could transfer her perception on the scenario into other settings. However, she pointed out phenomenon like global warming, droughts, water shortages related with environment in a general context. Therefore, she was classified into Level 1 for STS 3.

*Table 4.53: Deniz's level of STS 3*

| STS | Category | Level |
|---|---|---|
| STS 3- The ability to make generalizations | Generalizations on environmental aspect | Level 1: Identifies one aspect of sustainable development while making generalizations |

#### 4.6.2.4.STS 4- Understanding Hidden Dimensions of the System

During the interview, Deniz pointed out three hidden dimensions, which were water shortages, global warming and genetically modified organisms. Accordingly, she was classified into Level 3 for STS 4.

> ***About global warming and water shortages:*** "Damaging water resources means damaging the life source for all living organisms. It may cause extinction of species and destruction of natural balance. Our country can face with water shortages because of these actions. Besides, losing fresh waters can support global warming." (Question 12)
>
> ***About GMOs:*** "In the future, Kızılırmak will dry out and turn into an unproductive land. Agriculture with GMOs and chemicals are common nowadays, but they are harming nature." (Question 11)

*Table 4.54: Deniz's level of STS 4*

| STS | Category *(Hidden dimensions)* | Level |
|---|---|---|
| STS 4- Understanding hidden dimensions of the system | Global warming<br>Water shortages<br>GMOs | Level 3: Identifies three or more hidden dimensions from the scenario |

#### 4.6.2.5.STS 5- The Ability to Understand the Cyclic Nature of the Systems

When Deniz's concept map and interview was analyzed, it was observed that she was able to see the cyclic nature of the scenario. A quotation taken from her explanation of her concept map is presented below. Her response has the evidence for her cyclic thinking of the system, but she does not include social aspects in that cycle. Thus, she was classified into Level 2 for STS 5.

> "There is a lake ecosystem in Kızılırmak. At first, footprints of buffalos provide shelter for fishes and frogs. At the same time, buffalos are living in the wetlands and grasslands in the area. If fish population is increased, fishers will gain more money. Increasing in buffalo population may also support the protection of wetlands and this will support the insect population in the area." (Question 6)

*Table 4. 55: Deniz's level of STS 5*

| STS | Category *(Cyclic nature of the system)* | Level |
|---|---|---|
| STS 5- The ability to understand the cyclic nature of the systems | Explains cyclic nature of the system for environmental and economic aspects. | Level 2: Explains cyclic relations in the scenario but does not includes all aspects of sustainable development. |

#### 4.6.2.6.STS 6- Thinking Temporally: Retrospection and Prediction

While making predictions on scenario Deniz focused on environmental and economic aspects of sustainable development. Because she did not consider social aspect to her predictions, she was classified in Level 2 for STS 6.

> "With agriculture, every year Kızılırmak basin will be damaged more. It will result in drought and extinction of species. Even though agriculture may be beneficial for local economy, it will have negative impacts on biodiversity. Additionally, while there will be more fruits and vegetables, production of dairy products will decline. After fresh water resources are polluted, it will be challenging to reverse these negative effects. Destruction of natural balance in the region can support global warming. It will not be a bright future." (Question 11)

*Table 4.56: Deniz's level of STS 6*

| STS | Category *(Future predictions)* | Level |
|---|---|---|
| STS 6- Thinking temporally: Retrospection and prediction | Future predictions on environmental aspects<br>Future predictions on economic aspects | Level 2: Makes future predictions for two aspects of sustainable development |

#### 4.6.2.7.STS 7- Developing an Empathy with Other People and Non-Human Beings

In general, Deniz developed empathy with other people in the area from the economic perspective. Nevertheless, it cannot be clearly observed that she could develop empathy with non-human beings. Even though she stated that water is a vital source for every living being, there was no elaboration on this statement. Therefore, she was classified into Level 2 for STS 7.

> "If I were a buffalo breeder and all fields around me were being turned into agricultural lands I may not be able to hold on to my profession. Because there would not be enough grasslands for buffalos, I may need

to buy food to feed my animals. It will decrease the quality of the dairy products obtained from these animals as well as it brings an economic load. So, I cannot not carry out buffalo breeding anymore and will have to engage in agriculture." (Question 15)

*Table 4.57: Deniz's level of STS 7*

| STS | Category *(Empathy)* | Level |
|---|---|---|
| STS 7- Developing an empathy with other people and non-human beings | Empathy with other people | Level 2: Struggle to develop empathy with both other people and non-human beings |

#### 4.6.2.8.STS 8- Recognizing Own Responsibility in The System

Deniz's response for the question about human and nature relationship, was including clues of her recognition of her responsibility. Even though Deniz acknowledges the results of her actions in nature as a human being, she did not state any personal connection with the presented scenario. Thus, she was classified into Level 2 for STS 8.

"We [as human beings] are in a complete interaction with nature but people manipulate nature way too much. On the other hand, we need to synchronize with nature instead of making it to synchronize with us." (Question 12)

*Table 4.58: Deniz's level of STS 8*

| STS | Category *(Personal relation)* | Level |
|---|---|---|
| STS 8- Recognizing own responsibility in the system | Taking responsibility | Level 2: Struggle to make connections between issue and personal life & taking responsibility |

#### 4.6.2.9.STS 9- Developing a Sense of Place

Deniz stated biophysical and political dimensions of the Kızılırmak in her responses to the questions 17 and 18. For biophysical dimension she pointed out the natural balance in the area. For political dimension, she stated the role of the Kızılırmak basin in the national economy.

> ***About politic economic meaning:*** "I consider Kızılırmak as a natural value. People are doing fishing and animal breeding in the area. It is also a resource for humans, for food and for economy. Additionally, protection of this habitat is vital for natural balance worldwide. Because it may affect global warming or natural cycles." (Question 17)
>
> ***About biophysical meaning:*** "Even though I did not realize how Kızılırmak influences my life before, it is important for me. If we are sharing this world, having the natural habitat and natural balance without chemicals is important." (Question 18)

*Table 4.59: Deniz's level of STS 9*

| STS | Category *(Sense of Place)* | Level |
|---|---|---|
| STS 9- Developing a sense of place | Biophysical dimension<br>Politic- Economic dimension | Level 2: Defines place as including two dimensions |

### 4.6.3. Deniz's Definition of the System

Deniz defined system by emphasizing the interactions between its components. Her example of the system depicts a cycle inside an ecosystem. The definition and her response are given below.

> "A cycle with elements which are effecting each other in a continuous relationship… Think about a lake. Starts with the vaporization of water in the lake then condensation of it on a mountain top and turning into the soil again. It feeds the groundwater resources in there. Soil will filtrate this water and makes it a fresh water source underground. May

be plants will use it. Then it will turn lake again to be used by other animals. It is a continuous cycle…The lake, water, animals, plants, rivers, air, humans, soil, trees would be the elements of this system." (Questions 19 & 20).

### 4.6.4. Summary for Deniz's Systems Thinking Skills

Deniz was classified in Level 3 for only two systems thinking skill, which are STS 1 and STS 4. These two systems thinking skills showed the highest ranks for all participants. However, she portrayed a moderate rating for other six systems thinking skill *(STS 2, STS 5, STS 6, STS 7, STS 8)*. The only systems thinking skill she scored in Level 1 was "the ability to make generalizations" which has low scores for other participants, too. Additionally, Deniz's systems definitions showed that she has a basic understanding for systems. As a matter of fact, she explained water cycle as the example of the system, which is a concept used in the systems thinking literature (see Chapter 1).

*Table 4.60: Deniz's overall STS levels*

| Systems Thinking Skills (STS) | LEVEL |
|---|---|
| STS 1- Identify components of a system and processes within the system | 3 |
| STS 2- Identify relationships among the system's components | 2 |
| STS 3- The ability to make generalizations | 1 |
| STS 4- Understanding hidden dimensions of the system | 3 |
| STS 5- The ability to understand the cyclic nature of the systems | 2 |
| STS 6- Thinking temporally: Retrospection and prediction | 2 |
| STS 7- Developing an empathy with other people and non-human beings | 2 |
| STS 8- Recognizing own responsibility in the system | 2 |
| STS 9- Developing a sense of place | 2 |

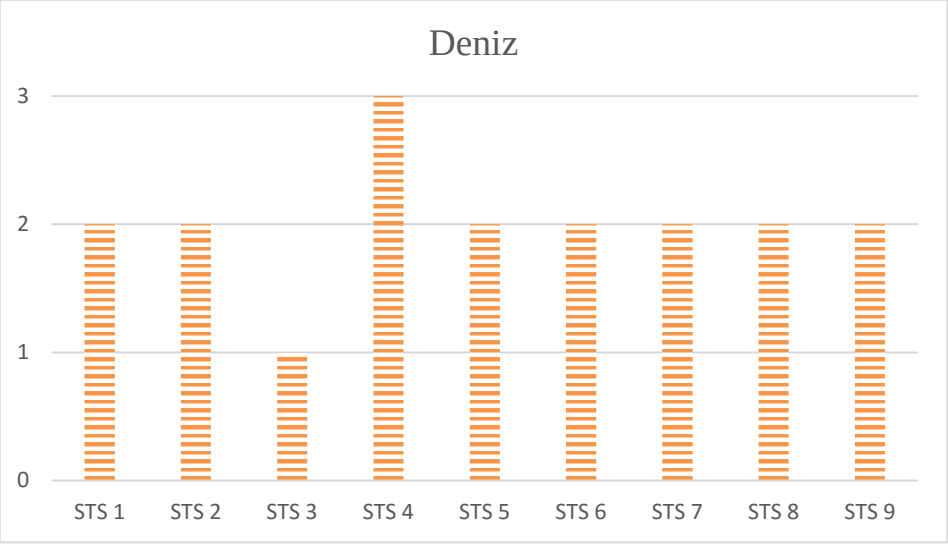


*Figure 6: Deniz's STS levels*

# CHAPTER 5

# DISCUSSION, CONCLUSION AND IMPLICATIONS

In this chapter, summary of the study, discussion, conclusion and implications of the findings, and recommendations for further research are presented.

## 5.1.Systems Thinking Levels of Pre-Service Science Teachers

In this thesis pre-service science teachers' levels of systems thinking are analyzed. Systems thinking skills are determined based on the systems thinking skills defined by Ben-Zvi Assaraf and Orion (2005) and Karaarslan (2016).

The first skill investigated in this thesis was identifying components of a system, and processes within the system (STS 1). Identifying components and processes were presented in Ben-Zvi Assaraf and Orion (2005) as the initial skill of systems thinking. In the literature, this skill was discussed in the context of water cycle (Ben-Zvi Assaraf, 2005; Lee et al., 2017); climate system (Shepardson et al. 2014); rock and carbon cycle (Sibley, Anderson, Heidemann, Merrill, Parker & Szymanski, 2007); human circulatory system (Raved & Yarden, 2014); ecosystems (Eilam, 2012) and sustainable development (Karaarslan, 2016). Researchers implied that with implementation identifying different components of a system can display an improvement (Ben-Zvi Assaraf & Orion, 2005; Raved & Yarden, 2014). Similar with Karaarslan (2014), in this thesis ability to identify components and processes evaluates the ability to point out the components and processes within the scenario, from all aspects of sustainable development, but there was not any

implementation. Almost all participants were reached at the highest rank for this skill. However, when findings examined in detail it was observed that participants were mostly concentrated on environmental aspect of sustainable development while discussing the scenario.

Identifying relationships among the systems components was the second systems thinking skill measured in this study (STS 2). In this thesis components and processes were categorized as environmental, economic and social and relationships were investigated between or within these categories. This systems thinking skill was adapted from the study of Ben-Zvi Assaraf and Orion (2005). The authors observed students tend to describe relationships between components which shows apparent connections. It is also noted that there is a correlation between the components and relationships students identified. Students struggle to finding out connections between the systems components was reported in different research papers. (Hmelo- Silver & Pfeffer, 2004; Raved & Yarden, 2014; Shepardson et al., 2014). It is noted that students have a lower achievement in connecting components from different levels organization (Raved & Yarden, 2014). Even though Karaarslan (2016) investigated this STS for pre-service teachers, she was also asserted this skill as a compelling ability. Moreover, Lee (2015) stated that teachers were not successful in reporting different connections between the subsystems inside a bigger system. Findings of this thesis also showed a similar picture. Most of the interactions found by participants contained the environmental components which were also the most dominant aspect of the STS 1. On the other hand, the interactions named in between different aspects of sustainable development were limited in number, and only one participant was rated in Level 3 for this skill. It can be claimed that having a concrete perspective on different components of the system is a priority for making connections between these components.

The third systems thinking skill discussed was ability to make generalizations (STS 3). It was stated that one can generalize a concept into other contexts if the core idea is fully perceived (Goldstone & Wilensky, 2008). Transferring the thinking scheme of a subject to other contexts requires comprehension of the variables without memorization (Lyons, 2014). In their research on students' systems thinking abilities Ben-Zvi Assaraf & Orion (2005) asserted that before implementation generalizations of students were focused on the components that were identified and discussed in the context of water cycle. Accordingly, in this research participants were made generalizations on the most common aspect within their answers while making generalizations: environment. This skill was one of the systems thinking skills which has lowest achievements in this study. Therefore, making generalizations can be considered as a complex ability if there was not a familiarity to the subject before.

Identifying hidden dimensions (STS 4) was the fourth skill explored in this thesis. It is stated that systems thinking includes finding out the components which are not explicitly defined (Ben-Zvi Assaraf & Orion, 2005). This skill was issued in various studies on systems thinking in education and considered as a challenging ability. It is observed that both students and teachers tend to discuss less complex and components which they have primary information on them (Golick et al. 2017; Lee, 2015; Sibley et al., 2007). Ben-Zvi Assaraf and Orion (2005) resulted that understanding hidden structures require in depth inquiry on the system that can be improved by implementation. In the ESD context, recognizing hidden dimensions enables to comprehend the interactions between variables and problems of daily life about environmental, social and economic phenomena like, climate change, population growth and poverty (Karaarslan, 2016). Eilam (2012) observed that experiential knowledge has positive affect on students' ability to identify implicit components in an ecosystem. Accordingly, in this thesis, it is noticed that using a real-life

scenario and an in-depth discussion on this scenario can provide a high achievement for finding out hidden structure.

Understanding the cyclic nature of the system (STS 5) was the fifth systems thinking skill defined in this thesis because it represents the integrated structure of the system. This skill asserts that the cyclic relations exist in every part of life and world is constituted by these interactions (Ben-Zvi Assaraf & Orion, 2005). Accordingly, it is stated that finding cyclic interactions among different levels of organization is not a common ability among students (Hmelo- Silver et al., 2007, Shepardson et al., 2014). Even though there is an agreement on the fact that an incessant process is ongoing in a system, focus is on the subjects specified previously (Lee, 2015; Sibley et al, 2007). Sustainable development also portrays a cyclic nature with the continuous relations between its different branches. However, in this thesis, it is observed most of the participants pay attention to the environmental aspect, which is the most renowned component of sustainable development, while describing the cyclic relationships. This finding implied that cyclic thinking between different concepts is not easy to achieve. However, comprehension of this skill is vital to consider a system as a unified structure and predict the consequences of an action.

The sixth skills investigated in this study was ability to thinking temporally; retrospection and prediction (STS 6). This skill is about acknowledging that present actions will have future results and making sensible connections between future, present and past (Ben-Zvi Assaraf & Orion, 2005). Karaarslan (2016) also drew attention to the importance of temporal thinking in terms of education for sustainable development. It was stated that ability to evaluate past, present and future events together enables to discover diverse solutions for future in terms of sustainability. In this thesis, it is observed that environmental aspect steps forward in the future predictions, in accordance with the other STSs. However, to raise an awareness for the sustainable

development, evaluating future outcomes of the present actions also from economic and social aspects holds a vital importance.

Developing empathy with other people and non-human beings (STS 7) is the seventh skill studied in this thesis. This skill derived from the Karaarslan (2016)'s study consists two divisions: empathy with non-human beings and empathy with other people. The world is a unified structure with all people and other living and non-living components on them. It is defined that developing empathy makes achievable to comprehend this fact (Karaarslan, 2016). Moreover, feeling empathy towards other people and non-human life defined in the socio-emotional domain and listed as one of the key competencies of sustainability. (UNESCO, 2017). In this thesis is was observed that developing empathy brings a positive attitude to participants. Considering other people's perspectives allows to construct solutions for the problems in the system that comprise everyone. Additionally, developing empathy with non-human beings helps to employ a more ecocentric thinking on sustainable development.

Recognizing own responsibility in the system (STS 8) was the eight systems thinking skill explored in the study. Acknowledging own responsibility was also stated as one of the behaviors to become a global citizen who interests in generating solutions to the worldwide problems of sustainability (Choi, Lee, Shin, Kim, & Krajcik, 2011). Karaarslan (2016) described this skill as being conscious about that personal actions can have effects on nature and life of other people and taking responsibility for these personal choices. The author defined the qualified teachers for ESD as the ones who transfer the environmental, social, and moral values to their students. Besides, taking responsibility was named as the most vital skill for students to achieve personal and social integrity and being a conscious citizen (Zoller, 2011). Additionally, taking responsibility in local and global settings also addressed as a key competency in education for sustainable development (UNECE, 2005). In this study, ability to take responsibility of participants were analyzed by using a

real-life scenario. The real-life scenario provided participants to make personal connections with an issue related to sustainable development. However, in order to show responsibility about the scenario, it is necessary for them to realize the results of their own actions. Therefore, as a systems thinking skill, recognizing own responsibility, involves personal habits and perspective.

The ninth skill reviewed in this thesis was developing a sense of place (STS 9). Sense of place was defined as one of most complex systems thinking skills. It is a multi-dimensional concept which facilitates approaching issues in a detailed perception and developing a relationship between places and individuals in different dimensions (Karaarslan, 2016). There are four elements identified in this concept: biophysical, psychological, socio-cultural and political-economic. For developing a strong understanding about a place, it is necessary to conceive all these different elements together (Ardoin, 2016). It is stated that biophysical dimension is the most featured dimension among teachers in ESD (Egger et al., 2017). Developing a sense of place was utilized in this thesis because there is a description of a specific place in the real-life scenario employed for this study. On the other hand, in accordance with the other STSs, participants mostly showed a tendency to interpret that place in terms of environmental characteristics, namely, biophysical dimension. Demonstration of STS levels of participants is presented in the Figure 7.

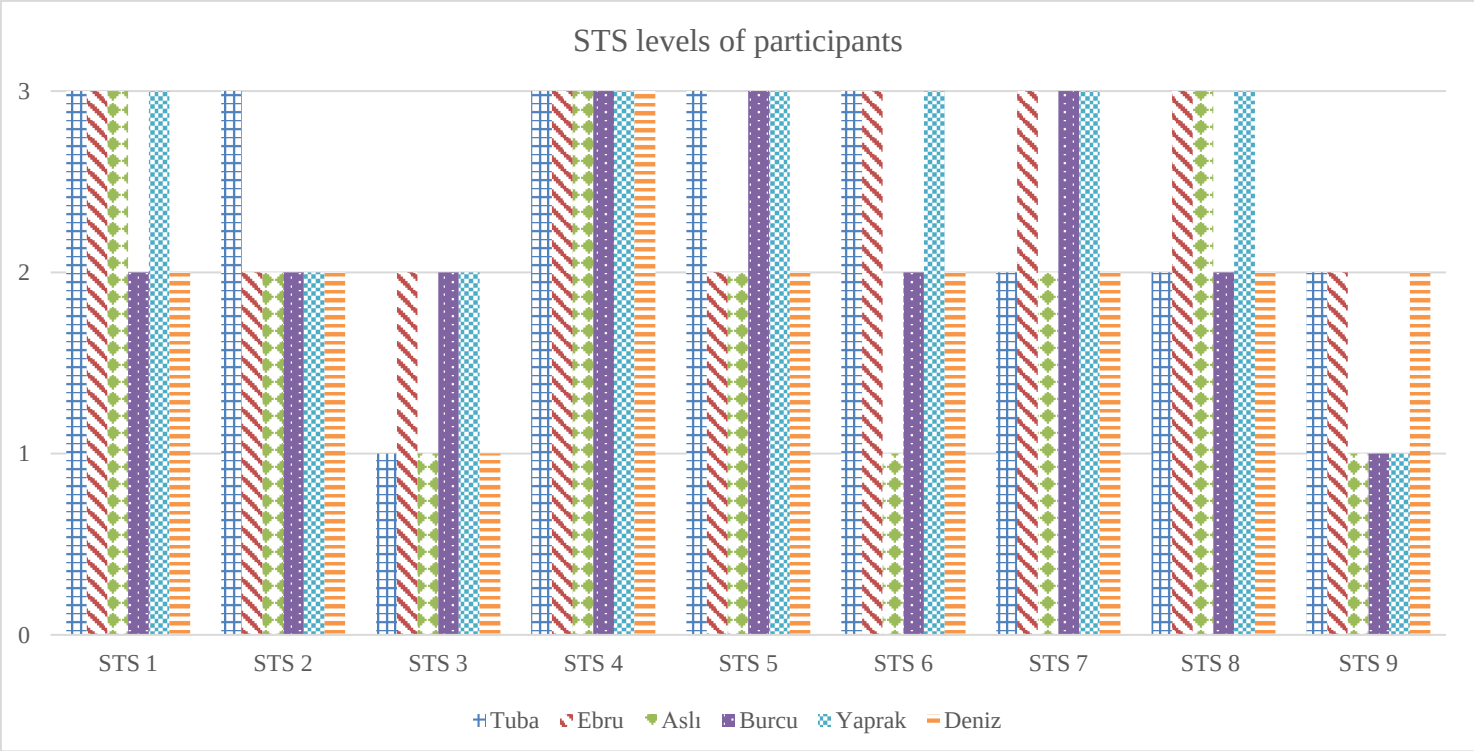


*Figure 7: STS Levels of all participants*

To sum up, findings of this study proposed a nonhierarchical model for systems thinking skills. The highest achievement is observed at finding hidden dimensions (STS 4), which was considered as one of the most challenging skill in the previous research. However, in this study, in depth analysis of the scenario with interviews put participants into a detailed reasoning practice. In other words, they were able to discuss the topic in different perspectives to find out hidden dimensions. In addition, it was observed that, participants' reactions to the scenario was deeply related with their personal experiences. Participants who have spent time in the nature were mostly addressed the importance of nature while other participants noticed the economic concerns in the scenario.

All in all, it is clearly inferred that there is not a strict pattern in development of systems thinking skills. There is nonhierarchical order between the skills examined in this thesis. Moreover, there is a certain systemic conception was observed in participants' definitions of system that can be improved with implementation.

## 5.2.Pre-Service Science Teachers' Conceptions of Sustainable Development

Another purpose of this thesis was to explore pre-service science teachers' conceptions of sustainable development. Sustainable development is as an integrated and complex concept which includes dynamic relationships within environmental, economic and social aspects (United Nations, 2002). It is emphasized the significance of sustainable development in education in order to raise students as responsible citizens who have the necessary decision-making abilities considering sustainability. To achieve this goal, teachers have a responsibility to be aware of the connections between environmental, economic and social aspects. This connected structure of sustainable development requires emphasis on an integrated thinking scheme, rather than discussing these concepts in separated settings (Sleurs, 2008).

Raising awareness on sustainable development among teachers was also addressed as a tool to provide solutions to environmental and social problems (Nolet, 2009). On the other hand, it is reported that environment forms a center of focus for science teachers while discussing sustainable development. Teachers have a preconception that protection of nature can assist sustainable development. To construct a future with conscious citizens who considers sustainable development, teachers need to assimilate an adequate understanding for sustainable development (Sagdic, 2013).

Moreover, it is claimed that the reason behind teacher's insufficient understanding of sustainable development is the lack of emphasis on sustainable development in teacher education programs. Mills and Tomas (2013), remarked that pre-service teachers have lack of ability to express their opinions on issues concerning sustainable development. However, teachers who participated in a learning processes on sustainability feel more responsible to raise their students as conscious citizens and increase the awareness on sustainability in their community (Egger et al., 2017).

Findings presented in this thesis also showed outcomes compatible with the previous research. First of all, there is an apparent dominance of environmental aspect in all systems thinking skill. Environment related components and relationships constituted the major part of STS 1 and STS 2. There was only one participant who linked components from all aspects of sustainable development while expressing the relationships. Moreover, it was observed that participants were mostly making generalizations (STS 3) on environmental aspect. They give examples from other environmental problems they experienced or witnessed. For cyclic relationships (STS 5), it is noticed that participants were describing cycles in the nature mostly. Especially emphasis on social components were weak. Accordingly, future predictions (STS 6) were also dominantly involve environmental inferences. Moreover, it was observed that all participants explained Kızılırmak basin in terms of biophysical meaning

(STS 9). Additionally, all six participants attended to the interviews were asked to consider sustainable development based on the given real-life scenario. Half of them directly pointed out that sustainable development is about protecting the environment. One participant claimed that there are other aspects in sustainable development, but she cannot name them. On the other hand, two participants regarded the interaction between economy with environment while defining sustainable development.

In conclusion, these findings can be expressed by participants' low levels of understanding sustainable development. Incomplete cognition of the concept restrains science teachers from providing sufficient explanations for sustainable development in a context.

### 5.3.Use of Real-Life Scenario for Assessment of Systems Thinking

In this study a real-life scenario was used as an assessment tool for determining the systems thinking skill levels of participants. Since systems thinking skills was evaluated in terms of sustainable development the real-life scenario was chosen considering it includes all aspects of sustainable development and reflects the interactions between them.

It was addressed that real-life scenarios are functional instruments to evaluate systems thinking skills like identifying components and relationships within the system (Karaarslan, 2016). In addition, using real-life cases is a common practice in the context of sustainability and environmental education. It was asserted that having a background knowledge on an environmental issue creates a wider perspective for reasoning about the solutions for it. For example, if a person did not have a chance to observe the negative effects of chemical fertilizers, it will not likely to for her to consider the impacts on environment during the decision-making process about using chemical

fertilizers (Kortenkampand & Moore, 2001). Moreover, Tuncay (2010), discussed that using real cases clearly expresses the complexity of environmental problems for individuals. This perception facilitates for participants to use critical thinking skills during the interviews on the issue. Additionally, it was expressed that engaging in examinations about real problems ensures participants to make more meaningful deductions. Also, real-life cases provide individuals to consider different aspects in the case (Ellis & Weekes, 2008). It was also explained that real-life scenarios present real problems to be discussed and improve individuals' problem-solving abilities. They depict the constrains and struggling decisions of everyday life from different perspectives (Remington- Doucette et al., 2013).

The presented thesis employed a local real-life example to discuss sustainable development and systems thinking. The difference of local and global problems was discussed in several studies. The problems that are not physically connected with the individuals can be considered insignificant and provides less motivation to take action (Connell, Fien, Lee, Sykes & Yencken, 1999). It was asserted that individuals feel more connected and ready to act when the addressed case is physically close to them. On the contrary, it was observed that it is challenging to comprehend reality of the scenario if it was presented in global context (Layrargues, 2000). In global context it was noticed that participants show more oriented to define the problem while local contexts display more motivation to solve problems. In other words, individuals tend to spend more time on finding solutions for local problems rather than just describing the problem (Purzer, Chen & Yadav, 2010).

In conclusion, use of real life scenario to assess systems thinking skills displayed consistent results in this study. First of all, a real-scenario introduced a real problem to discuss and it was noticed that participants internalized the concept easily. It was observed that real-life scenarios provided similar findings on the systems thinking levels of pre-service science teachers with the

previous research on systems thinking. Additionally, to allow individuals to discuss ecologic, economic and cultural effects of an action it is vital to give them an insight on benefits and disadvantages of their decisions (Balgopal, Wallace & Dahlberg, 2012). Implicit interview questions supported participants to view different perspectives on the scenario and enable them to discuss the scenario in detail. In addition, this extensive perspective develops participants' empathy towards other people and non-human beings. The fact that most of the participants shared their personal experiences during the interviews also implied that commenting on a real scenario encourage them to a deeper thinking.

## 5.4.Conclusion and Implications

There are several conclusions derived from this thesis. Firstly, pre-service science teachers' systems thinking skills was assessed by using a real-life scenario and interviewing. Findings showed consistent results with other research on systems thinking. It is concluded that real-life scenario provides a meaningful tool to assess systems thinking skills of individuals in the context of sustainable development. Secondly, there are nine systems thinking skills defined in this thesis, adapted from different resources. It was observed that these STSs can be used in the context of sustainable development. Thirdly, it was observed that pre-service science teachers have a common understanding for systems. However, because of their weak conceptions on sustainable development they were not able to fully interpret the environmental, social and economic aspects of sustainable development into a systemic perspective. Lastly, this study did not include any implementation to picture the current state of participants. It was observed that personal experiences are affecting their sustainable development conceptions. They refer to their experiential knowledge more than their professional knowledge while commenting on the scenario.

The results also have important implications for systems thinking and ESD researchers, curriculum developers and science teachers. Systems thinking is a significant thinking skill which can be adapted into different contexts of daily life. This study implied that systems thinking can be studied in ESD without concentrating on any specific discipline. The importance of sustainable development and ESD specifically addressed in national science education curriculum (Ministry of National Education, 2017). Therefore, the assessment method proposed in this thesis can be adapted in different contexts. It can be even used as a part of a course curriculum about sustainable development.

Furthermore, from the results of this thesis it was also inferred that systems thinking, and sustainable development can be discussed in the same context. Findings showed that there is need for special emphasis on the meaning of sustainable development. Teaching educators can use the results of this thesis to improve the courses which issues sustainable development in its context. Approaching sustainable development from a systems perspective can provide better comprehension of the integrated nature of sustainable development.

## 5.5.Recommendations

This thesis proposes some recommendations for future research. Firstly, in this study a real-life scenario which has implicit connections of three aspects of sustainable development; environment, economy and society was used. This scenario was presenting a local incident. It is recommended to use different real-life scenarios to evaluate the utilization of this tool in the systems thinking literature. Moreover, a scenario focuses on a real-life situation in the global context can be used for future research, in order to make a comparison between the results of global and local contexts. Nevertheless, the interview questions were specifically designed for the selected real-life scenario in this thesis. In case of changing the scenario, there should be new questions adapted for the

new context. Additionally, the framework of this thesis was constructed with the systems thinking skills defined by Ben-Zvi Assaraf and Orion (2005) and Karaarslan (2016). On the other hand, there are different frameworks defined in the literature. Real-life scenarios can also be used in these frameworks as an assessment tool.

Secondly, there were nine systems thinking skills examined in this study with a real-life scenario. Real-life scenarios can be used as a tool to assess middle school students' systems thinking skills. It is recommended to future researchers to use this scenario in the studies sampling students. However, some of the systems thinking skills was identified as challenging skills. Thus, with students, it is recommended to use the skills with highest achievements.

Thirdly, participants' individual characteristics can be examined in detail. For instance, in this study participants were female pre-service science teachers. Repeating the study with male participants is recommended in order to discover the gender's role in systems thinking skills. Additionally, the real-life scenario and interview questions developed in this study did not feature characteristics specific to the science education. It is recommended to study systems thinking skills in different disciplines and different subjects in education. Therefore, it is also possible to select participants from different teaching disciplines to evaluate the influence of professional background. In fact, studies with samples from different fields of professions like business, medicine, engineering or farming can also employ the assessment tools in this thesis.

Lastly, it is suggested to practice this research with in-service teachers, in order to discover the effects of experience on systems thinking skills. It can be investigated if they feel responsibility to transmit their systems thinking abilities to their students and if students' academic achievements are influenced by teachers' perspective.

In conclusion, this thesis aimed to present an insight for researchers who are interested in implementing systems thinking to education. Especially in Turkey, systems thinking is a concept that requires further exploration. Systems thinking holds a wide potential for researchers because complex systems constitute almost every part of life. It is recommended to study systems thinking in education, because schools and teachers have the opportunity to raise future citizens. Curriculum developers from different disciplines can use conclusions of this study as a source for understanding the role of systems thinking in comprehension of a concept. To build a bright future survived from the problems of 21$^{st}$ century, possessing higher order thinking skills like systems thinking have a significant role.

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# APPENDICES

## APPENDIX A.

### THE REAL-LIFE SCENARIO (TURKISH)

Deltalar, oluşturdukları zengin biyolojik çeşitlilik ve verimli tarım arazileri nedeniyle bütün canlılar için dünyanın çok önemli alanlarını oluşturuyor. Uluslararası öneme sahip, Kızılırmak deltası da doğal özellikleri büyük ölçüde korunabilmiş, ülkemizdeki en büyük deltalardan birisi.

Samsun'un Bafra ilçesindeki Kızılırmak deltası 57 bin hektarlık bir alana yayılıyor. İçerisinde 22 göl, 12 bin hektarlık sulak alan bulunuyor. Kızılırmak Deltası'nda bir de kuş cenneti bulunuyor. Türkiye'de yaşayan 465 kuş türünün 328'i deltada görülebiliyor. Bölge zengin çalı örtüsü ve çok büyük sayıda böcek popülâsyonuna sahip olması nedeniyle Karadeniz üzerinden göç eden ötücü kuşlar için önemli bir dinlenme ve beslenme alanı oluşturuyor. Bunun yanı sıra bu bol çeşitli canlı hayatı deltaya eşsiz bir görünüm kazandırarak bölgeyi çevredeki insanlar için de bir dinlenme merkezi haline getiriyor.

Bölge insanı sulak alandan tarım için sulama suyunu sağlamasının yanı sıra, balıkçılık, hayvan yetiştiriciliği, saz kesimi gibi etkinliklerle yararlanıyor. Delta içerisinde tarım alanları önemli yer tutuyor. Ülkemizin kışlık sebze tarımının önemli bir bölümü burada yapılıyor. Delta hayvancılık için de oldukça elverişli. Manda ve sığır bölgedeki en yaygın hayvanlar.

Mandalar zamanlarının çoğunu suyun içinde geçiriyor. Balıklar ve kurbağalar da mandaların ayak izlerine yumurta bırakıyor. Mandalar otlarken bulundukları bölgedeki sulak alan bitkilerinin dağılımını da kontrol etmiş oluyor. Bu sulak alan bitkileri de başta kuşlar olmak üzere deltada yaşayan pek çok canlı için yuva yapmaya elverişli alanlar oluşturuyor.

Ancak 1990'lı yıllarda bölgede yaşayan manda sayısı on binden fazla olmasına rağmen 2000'li yıllarda iki bine düşmüş. Manda ürünlerinin bölge insanı için ekonomik değerini yitirmesi ve mandaların yılın büyük bölümünü geçirdiği sulak alanların kimyasal gübre ve ilaçlarla zarar görmesi bu sayının azalmasının en önemli nedenleri arasında. Manda sayısının azalmasıyla bölgedeki manda sahipleri için değerini yitiren sulak alanlar da kurutularak

tarlaya dönüştürülmeye başlanıyor. Böylece bölgede manda sayısı azalırken, tarım alanları artıyor. Bu durum birçok canlının yaşam alanının da yok olmasına yol açıyor. Tarım ilaçları da sulak alanların ve çevredeki otlakların kirlenmesine ve çevredeki canlılığın olumsuz etkilenmesine neden oluyor.

Bölge ekosisteminin sorunlarının çözülmesi amacıyla 2008 yılında bölgede mandacılığın yaşatılması ve manda sayısının arttırılması için "Kızılırmak Delta'sında Manda Sevdası" Projesi" başlatılıyor. Proje kapsamında bölge halkı manda yetiştiriciliği konusunda teşvik ediliyor. Hayvancılıkta son teknolojiler ve manda ürünlerinin pazarlanması konusunda eğitimler veriliyor. Bu çalışmalar kapsamında manda sütünün ve etinin farklı alanlarda kullanılması da teşvik ediliyor. Kızılırmak deltasına özgü manda lokumu ve daha önce manda sucuğu ve mozarella gibi ürünler de üretilmeye başlanıyor. Bölgedeki mandacılık çalışmaları teknolojik altyapıyla da desteklenmeye başlanıyor.

Bu çabalar sonucunda, son yıllarda bölgedeki manda sayısı on üç bine yükselmiş. 2015 yılı mayıs ayında birincisi düzenlenen "Delta'ya Manda Salınım Festivali" de bölgede manda yetiştiriciliğine verilen önemi vurguluyor. Samsun ili Manda Yetiştiricileri Birliği manda ürünlerinin patentini aldıklarını; manda sayısının arttırılmasının ve en az yirmi bine çıkarılmasının delta için önemli olduğunu açıklıyor.

**Kaynak:**

Erciyas Yavuz, K. (2011), Önemli bir doğa alanı: Kızılırmak deltası, Samsun Sempozyumu.

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## APPENDIX B.

## INTERVIEW QUESTIONS (ENGLISH)

**Demographic Questions:**

1. Year of Birth:
2. Grade:
3. Did you take any courses related to sustainable development or environment during your undergraduate education? If yes, please specify.
4. Where did you spend your childhood? (Village, small town, county or province)
5. Do you have a membership to a non-governmental organization or a student group related to environment? If yes, please specify. If no, did you attend activities of a non-governmental organization or a student group related to environment?
6. Did you hear this real-life scenario before?

**Interview Questions**

1. What is the main idea of this case?
2. What do you understand/infer from this case?
3. What are the components of this case?
4. What are the key words of this real-life case?
5. How many small incidents related to each other in this real-life case? What are the headlines of them?
6. Could you draw a concept map (or picture) to show the relationships among these components, and explain your drawing?

7. What are the effects of the changes in this real-life case? What are the positive and negative sides?
8. Could you suggest a title for this case?
9. What can you say about the communication between man and environment, based on this real-life case?
10. What can you say about sustainable development based on this case?
11. Could you describe the future of Kızılırmak, assuming people are engaged in agriculture instead of buffalo farming?
12. Could this real-life case be a threat to the human life and nature, in present and future?
13. Could the situation described in this case be a threat to the sustainable future?
14. Would there be any effect of raising the population of water buffalo in Kızılırmak delta? How?
15. If you were a buffalo farmer who lives in Kızılırmak delta, how would you react to this problem?
16. How would you design a project to solve the problems of the Kızılırmak delta?
17. What does Kızılırmak means to you?
18. Is Kızılırmak delta an important place for you? Why?
19. What is a system?
20. Can you give an example to a system? What are the features that show that this is a system?

# APPENDIX C.

## ETHICAL COMMITTEE APPROVAL OF METU

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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08 ŞUBAT 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof. Dr. Ceren ÖZTEKİN ;

Danışmanlığını yaptığınız yüksek lisans öğrencisi Melike ÖZTAŞ' ın ***"Fen Bilimleri Öğretmen Adaylarının Sistemsel Düşünme Becerilerinin Gerçek Yaşam Öyküleri Kullanılarak Değerlendirilmesi"*** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2015-EGT-002** protokol numarası ile uygun görülmüştür.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Yrd. Doç. Dr. Pınar KAYGAN
Üye

Yrd. Doç. Dr. Emre SELÇUK
Üye

## APPENDIX D.

## TURKISH SUMMARY/ TÜRKÇE ÖZET

### Fen Bilimleri Öğretmen Adaylarının Sistemsel Düşünme Becerilerinin Gerçek Yaşam Öyküleri Kullanılarak Değerlendirilmesi

### GİRİŞ

Çağdaş toplum günlük hayatın içerisinde ekoloji, ekonomi ve toplumsal temelli pek çok karmaşık sistemsel yapı sunmaktadır. Bu sistemlerin çok yönlü yapısı, 21. yüzyılın getirdiği ikilemlerden etkilenen toplumun her alanı için yeni bakış açıları ve yöntemler geliştirilmesine olanak sağlamaktadır (Jacobson & Wilensky, 2006; Lesh, 2006). Bu karmaşık sistemler pek çok bütünleşik alt başlıklardan oluşmaktadır. Karmaşık sistemleri anlayabilmek için bu alt başlıklar arasında ilişki kurabilmek gerekir. Ancak söz konusu ilişkiler her zaman görünür olmayabilir. Bu özelliği karmaşık sistemlerin algılanmasını zorlaştırmaktadır (Hmelo-Silver & Pfeffer, 2004). Karmaşık sistemler içerisinde barındırdıkları örüntüler, dairesel ve bütünleşik yapısı ve sistem bileşenlerinin arasındaki ilişkiler ile karakterize edilebilir (Goldstone & Wilensky, 2008). Karmaşık sistemlerin kapsamlı tabiatı, bu kavramın sosyal bilimlerden yer bilimlerine farklı araştırma alanlarında ve işletme, sosyoloji, çevre, mühendislik, biyoloji, kimya, fizik ve sağlık gibi pek çok konuda çalışılmasına olanak sağlamaktadır (Hmelo-Silver & Azevdo, 2006; Jacobson & Wilensky, 2006).

21. yüzyıl becerilerinden biri olarak kabul edilen sistemsel düşünme hem bilim insanları hem de toplum için gerekli, bilim ve çevre ile ilişkili problemlerin çözümüne yardımcı olabilecek bir eleştirel düşünme becerisi olarak belirtilmiştir. Sistemsel düşünme, bir sistemi analiz ederek, değerlendirerek ve bu sistem üzerine akıl yürüterek "büyük resmi" görebilmeyi sağlayan bir yeterlik olarak tanımlanmaktadır (NRC, 2010).

Sistemsel düşünme bir üst seviye düşünme becerisi olarak kabul edilmektedir. Bir bütünün içerisindeki parçaları, ilişkileri ve toplam işleyişi görebilmeyi sağlayan bu düşünme becerisi sayesinde bireyler sistemdeki sorunları kolayca tespit edebilir ve muhtemel çözümleri öngörebilirler (Wylie, Sheehy, McGuinness, & Orchard, 1998; Zoller & Nahum, 2011).

Eğitim alanındaysa karmaşık sistemlerin çalışılması, fizik, kimya biyoloji ve sosyal bilimler gibi farklı bilimsel disiplinleri bir araya getiren eşsiz bir bakış açısı ve kuramsal çerçeve sunmaktadır (Jacobson & Wilensky, 2006). Fen bilimleri eğitiminde sistemsel yapılar içeren konular göze çarpmaktadır. Ancak bu yapıların sistem olarak değil, ayrı başlıklar halinde ele alındığı gözlemlenmiştir. Konuları parçalara ayırarak sunan fen bilimleri ders kitapları, öğrencilerin karmaşık sistemlerle ilgili bir sağduyu edinmelerine engel olmaktadır (Liu & Hmelo- Silver, 2009). Öğrenciler çoğunlukla kompleks sistemlerle ilgili doğrusal ve bileşenler arasındaki bağlantıları göz ardı eden bir anlatımla karşılaşmaktadırlar. Öte yandan karmaşık sistemlerin anlaşılması için farklı düzeylerdeki bileşenlerin aralarındaki ilişkilerin açıklanması ve bir ilişkiler ağının resmedilmesi gerekmektedir (Hmelo, Holton, &Kolodner, 2000; Hmelo- Silver & Pfeffer, 2004).

Fen bilimleri eğitiminde sistemsel düşünmeyle ilgili çalışmalara çeşitli konularda rastlanmaktadır: yer bilimleri (örn. su döngüsü, karbon döngüsü, kayaç döngüsü) (Ben-Zvi Assaraf & Orion, 2005; Gudovitch & Orion, 2001; Kali, Orion & Eylon, 2003; Scherer; Holder & Herbert, 2017; Sibley vd., 2007); insan vücudundaki sistemler, ekosistemler ve tozlaşma gibi biyolojik

sistemler (Eilam, 2012; Evagorou, Korfiatis, Nicolaou, Costantinou, 2009; Golick, Dauer, Lynch & Ingram, 2017; Liu & Hmelo-Silver, 2009; Hmelo-Silver, Marathe & Liu, 2011; Raved & Yarden, 2014; Riess & Mischo, 2010; Verhoeff, Warloo, & Boersma, 2008); ve sürdürülebilirlik (Nyugen & Bosch, 2013).

Bunlara ek olarak, fen bilimleri öğretim programının genel amaçlarından biri olarak vurgulanan (Ministry of National Education, 2017), sürdürülebilir kalkınma kavramı sistemsel bir bakış açısıyla ele alınabilir. Sürdürülebilir kalkınma içerisinde birbirleriyle ilişkili çevresel, sosyal ve ekonomik alt kavramları barındırmaktadır (United Nations, 2002). Sistemsel düşünme sürdürülebilir kalkınmanın öne sürdüğü bu bütünleşik yapıyı anlamlandırmak için önemli bir potansiyel taşımaktadır (Wheeler, 2000).

Ben-Zvi Assaraf ve Orion (2005) sistemsel düşünme üzerine "Hiyerarşik Sistemsel Düşünme Modeli" olarak tanımladıkları bir model geliştirmişlerdir. Araştırmacılar bu model içerisinde sistemsel düşünme ile ilgili sekiz beceri belirlemişlerdir. Bu becerilerden bazıları sistem içerisindeki bileşenleri ve işlemleri tanımlamak, bu bileşenler ve işlemler arasındaki ilişkileri tanımlamak, sistemin döngüsel yapısını tanımlamak, sistem içerisindeki gizli boyutları fark edebilmek, sistem hakkında genelleme yapabilmek ve sistem içerisindeki etkileşimlerin gelecek etkilerini fark edebilmek olarak tanımlanmıştır. Bunun yanı sıra, Karaarslan (2016) sistemsel düşünceyi sürdürülebilir kalkınma çerçevesinde değerlendirerek, çalışmasında 12 adet sistemsel düşünme becerisi tanımlamıştır. Bunlardan bazıları şöyledir: diğer insanlar ve canlılarla empati yapabilmek, sistem içerisinde kendi sorumluluğunun farkına varabilmek ve bir mekân algısı geliştirebilmektir.

Bu iki çalışmadan derlenen dokuz sistemsel düşünme becerisi (SDB) bu yüksek lisans tezinin genel çerçevesini oluşturmak üzere kullanılmıştır (Tablo 1).

*Tablo 1: Sistemsel Düşünme Becerileri*

| | Sistemsel Düşünme Becerileri (SDB) |
|---|---|
| SDB 1 | Sistem içerisindeki bileşenleri ve işlemleri tanımlamak |
| SDB 2 | Sistem içerisindeki bileşenler ve işlemler arasındaki ilişkileri tanımlamak |
| SDB 3 | Sistem hakkında genelleme yapabilmek |
| SDB 4 | Sistem içerisindeki gizli boyutları fark edebilmek |
| SDB 5 | Sistemin döngüsel yapısını tanımlamak |
| SDB 6 | Sistem içerisindeki etkileşimlerin gelecek etkilerini fark edebilmek |
| SDB 7 | Diğer insanlar ve canlılarla empati yapabilmek |
| SDB 8 | Sistem içerisinde kendi sorumluluğunun farkına varabilmek |
| SDB 9 | Bir mekân algısı geliştirebilmek |

**Çalışmanın Amacı ve Araştırma Soruları**

Bu çalışma fen bilimleri öğretmen adaylarının sistemsel düşünme becerilerinin düzeylerini sürdürülebilir kalkınma kavramı kapsamında belirlemeyi amaçlamaktadır. Bu çerçevede, bu tezde fen bilimleri öğretmen adaylarının sürdürülebilir kalkınmanın çevresel, ekonomik ve toplumsal bileşenleri arasındaki ilişkileri sistemsel bir yaklaşımla ele alıp almadığı incelenmiştir. Çalışmada tartışılan araştırma soruları aşağıdaki gibidir:

1- Fen bilimleri öğretmen adaylarının sürdürülebilir kalkınma kavramı açısından sistemsel düşünme becerileri hangi düzeydedir?
2- Fen bilimleri öğretmen adaylarının sürdürülebilir kalkınma kavramına dair anlayışları nedir?

## YÖNTEM

Bu çalışma fen bilimleri öğretmen adaylarının sistemsel düşünme becerilerini değerlendirmeyi amaçlamaktadır. Karaarslan (2016)'nın da belirttiği üzere kişilerin kişisel geçmişleri sistemsel düşünme yeteneklerini etkileyebilmektedir. Buradan yola çıkarak bu tezde çalışma deseni olarak bir nitel çalışma yöntemi olan çoklu durum çalışması kullanılmasına karar verilmiştir. Çoklu durum çalışması incelenen durumun detaylı olarak incelenmesine olanak sağlamasının yanı sıra toplu bir değerlendirme yapmayı da mümkün kılmaktadır (Stake, 2005).

### Katılımcılar

Bu çalışmaya Türkiye'de bir devlet üniversitesinde son sınıf öğrencisi olan altı fen bilimleri öğretmen adayı katılmıştır. Katılımcılara sırasıyla Tuba, Ebru, Aslı, Burcu, Yaprak ve Deniz olmak üzere rumuz isimler verilmiştir. Örneklem grubu oluşturulurken üç adet koşul belirlenerek amaçlı örneklem yöntemi kullanılmıştır. Bütün katılımcıların aynı üniversitede öğrenci olmasına, son sınıf öğrencisi olmalarına ve sürdürülebilir kalkınma konusuna ilgileri olduğuna dair öğretim üyeleri tarafından tavsiye edilmiş olmalarına dikkat edilmiştir.

### Veri toplama araçları

Bu çalışmada fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini değerlendirmek amacıyla bir gerçek yaşam öyküsü ve bu öyküyle ilgili görüşme soruları kullanılmıştır.

Gerçek yaşam öyküsü katılımcıların okudukları öyküyle kişisel bir ilişki kurmalarına olanak sağlamayı amaçlamaktadır (Erdogan & Tuncer, 2009). Söz konusu öykü Kızılırmak havzasıyla ilgili bir "Kızılırmak Havzasını Mandalar Kurtaracak" başlıklı bir gazete haberinden yola çıkılarak ek kaynaklardan elde edilen bilgilerin de derlenmesiyle araştırmacı tarafından oluşturulmuştur. Öyküde Kızılırmak havzasındaki manda popülasyonun zaman içerisndeki azalışını konu almaktadır. Öyküye göre, manda ürünleri ekonomik değerini

kaybedince bölge halkı mandacılığı bırakıp tarıma yönelmiştir. Fakat tarımda kullanılan ilaçlar ve kimyasal gübreler çevreye zarar vermeye başlamıştır. Bunun yanı sıra mandaların eksikliği de ekolojik dengenin bozulmasına neden olmuştur. Bu nedenlerle bölge halkı çevresel sorunlarla yüz yüze gelmiştir. Bir sivil toplum örgütü bölge halkının sorunlarını çözmek amacıyla, bölgede mandacılığı geliştirmek adına bir proje başlatır. Proje kapsamında yapılan çalışmalar sayesinde manda sayısı arttırılmaya çalışılır. Bu gerçek yaşam öyküsü seçilirken içerisinde sürdürülebilir kalkınmanın bileşenleri olan çevre, toplum ve ekonomi hakkında bakış açıları sunmasına dikkat edilmiştir.

Söz konusu gerçek yaşam öyküsüne dayanarak katılımcılara sorulmak üzere altısı demografik olmak üzere 26 görüşme sorusu geliştirilmiştir. Görüşmeler katılımcıların tutumlarını, duygularını, düşüncelerini, deneyimlerini ve görüşlerini derinlemesine anlamayı sağlayan veri toplama araçlarıdır (Patton, 1990). Bu 20 açık uçlu soru içerisinde bazı sorular özellikle belirli sistemsel düşünme becerilerini ölçmek amacıyla sorulurken, bazı sorularsa her sistemsel düşünme becerisine kaynak sağlayabilecek niteliktedir.

Bu çalışmada yarı yapılandırılmış görüşme modeli uygulanmıştır. Yarı yapılandırılmış görüşmeler soruları düzenli bir çerçeveye sıkıştırmadan katılımcıların konu hakkında daha rahat ve detaylı fikir belirtebilmesine olanak sağlamaktadır (Merriam, 2009). Görüşme soruları, çalışmada izlenen yarı yapılandırılmış görüşme modelinde kullanılmaya uygun olarak açık uçlu sorular olarak tasarlanmıştır. Katılımcıları belirli bir fikre yönlendirmekten kaçınmak için doğrudan sistemsel düşünme becerilerini sorgulayan sorular yerine örtük anlamlı sorular tercih edilmiştir.

**Veri Toplama**

Veri toplama sürecinde görüşmeler araştırmacı tarafından kişisel olarak gerçekleştirilmiştir. Görüşmeye başlarken gerçek yaşam öyküsü katılımcılar tarafından okunmuş ve sonrasında katılımcılara görüşme soruları yöneltilmiştir.

**Veri Analizi**

Görüşme kayıtları araştırmacı tarafından yazılı hale getirilerek analiz öncesinde detaylı olarak incelenmiştir. Bu inceleme sonucunda her görüşme çalışmada kullanılan dokuz sistemsel düşünme becerisine uygun olarak kategorize edilmiştir. Her bir sistemsel düşünme becerisi için kararlaştırılan kategoriler ve sistemsel düşünme becerilerinin kısa tanımlamaları Tablo 2'de gösterilmektedir. Görüşme kayıtları incelenirken bu kategori ve tanımlardan faydalanılmıştır.

Elde edilen bulguların analizi için bu çalışmada kullanılan sistemsel düşünme becerilerine özel olarak bir rubrik geliştirilmiştir. Rubrik geliştirilmesi sırasında Karaarslan (2016)'ın sunduğu rubrikten faydalanılmıştır. Her bir sistemsel düşünme becerisi rubrik üzerinde üç düzeyde değerlendirilmiştir.

*Tablo 2: Sistemsel Düşünme Becerileri, Kategoriler ve Tanımlar*

| SDB | Kategoriler | Tanımlar |
|---|---|---|
| SDB 1- Sistem içerisindeki bileşenleri ve işlemleri tanımlamak | Çevresel bileşenler<br>Sosyal bileşenler<br>Ekonomik bileşenler | Çevresel bileşenler doğal kaynaklar (su, enerji, tarım ve biyoçeşitlilik), iklim değişimi, doğal afet yönetimi, kırsal kalkınma, sürdürülebilir şehirleşme; sosyal bileşenler insan hakları, cinsiyet eşitliği, kültürel çeşitlilik; ekonomik bileşenler; yoksulluk, kurumsal sorumluluk, pazar ekonomisi gibi başlıkları içermektedir (UNESCO, 2006; Karaarslan, 2016). |
| SDB 2- Sistem içerisindeki bileşenler ve işlemler arasındaki ilişkileri tanımlamak | Çevresel bileşenler arasındaki ilişkiler<br>Sosyal bileşenler arasındaki ilişkiler<br>Ekonomik bileşenler arasındaki ilişkiler<br>Çevresel ve ekonomik bileşenler arasındaki ilişkiler<br>Çevresel ve sosyal bileşenler arasındaki ilişkiler<br>Sosyal ve ekonomik bileşenler arasındaki ilişkiler<br>Çevresel, sosyal ve ekonomik bileşenler arasındaki ilişkiler | Bu beceri öyküden çıkarılan farklı bileşenler arasında bir ilişki kurmak ve bu bileşenlerin birbirlerini nasıl etkilediklerini açıklamayı içerir. Bu ilişkiler metinde doğrudan ya da dolaylı yoldan ifade edilmiş olabilir. |

*Tablo 2 (Devam)*

| | | |
|---|---|---|
| SDB 3- Sistem hakkında genelleme yapabilmek | Çevresel bileşenler hakkındaki genellemeler<br>Ekonomik bileşenler hakkındaki genellemeler<br>Sosyal bileşenler hakkındaki genellemeler | Bu beceri sistemin temel işleyişini benimsemeyi ve bu bilgiyi farklı ortamlara uyarlayabilmeyi içerir (Ben-Zvi Assaraf & Orion, 2005). |
| SDB 4- Sistem içerisindeki gizli boyutları fark edebilmek | Gizli boyutlar | Bu beceri sistemin içerisindeki doğrudan ifade edilmeyen gizli bileşenlerin farkında olabilmeyi içerir (Ben-Zvi Assaraf & Orion, 2005). |
| SDB 5- Sistemin döngüsel yapısını tanımlamak | Sistemin döngüsel doğası | Bu beceri dünyadaki döngülerin devamlılığını fark edebilmeyi içerir (Ben-Zvi Assaraf & Orion, 2005). |
| SDB 6- Sistem içerisindeki etkileşimlerin gelecek etkilerini fark edebilmek | Çevresel boyut hakkındaki tahminler<br>Ekonomik boyut hakkındaki tahminler<br>Sosyal boyut hakkındaki tahminler | Bu beceri her davranışın geçmişte bir nedeni ve gelecekte bir etkisi olduğunu fark etmeyi amaçlamaktadır (Ben-Zvi Assaraf & Orion, 2005). |

*Tablo 2 (Devam)*

| | | |
|---|---|---|
| SDB 7- Diğer insanlar ve canlılarla empati yapabilmek | Diğer insanlarla empati yapabilmek<br>Diğer canlılarla empati yapabilmek | Bu beceri farklı insanların bakış açılarını, motivasyonlarını ve duygularını anlayabilmeyi ve doğadaki diğer canlıları düşünerek hareket edebilmeyi içermektedir. |
| SDB 8- Sistem içerisinde kendi sorumluluğunun farkına varabilmek | Konu ve kişisel yaşam arasında ilişki kurabilme<br>Harekete geçebilme | Bu beceri kişilerin küresel problemlerdeki sorumluluğunu anlamalarını amaçlamaktadır (Karaarslan, 2016). |
| SDB 9- Bir mekân algısı geliştirebilmek | Biyofiziksel boyut<br>Psikolojik boyut<br>Sosyokültürel boyut<br>Politik- Ekonomik boyut | Bir mekân farklı anlamlar taşıyabilir. Bu beceride bir mekân biyofiziksel, psikolojik, sosyokültürel ve politik- ekonomik olmak üzere 4 boyutta değerlendirilmektedir (Ardoin, 2006; Karaarslan, 2016). |

# TARTIŞMA VE SONUÇ

## 1. Fen Bilimleri Öğretmen Adaylarının Sistemsel Düşünme Becerisi Düzeyleri

Bu çalışmada fen bilimleri öğretmen adaylarının sistemsel düşünme becerilerinin gerçek olaylar kullanılarak değerlendirilmesi incelenmiştir. Değerlendirme sonucunda katılımcıların sistemsel düşünme becerilerinin gelişimlerinin farklılık gösterdiği ve hiyerarşik olmayan bir düzlemde ilerlediği gözlemlenmiştir (Şekil 1).

Bu çalışmada ele alınan ilk sistemsel düşünme becerisi "sistem içerisindeki bileşenleri ve işlemleri tanımlamak" (SDB 1)'tır. Sistemin bileşenlerini tanımlamak sistemsel düşünmenin ilk basamaklarından biridir (Ben-Zvi Assaraf & Orion, 2005). Katılımcılardan beklenen kendilerine verilen gerçek yaşam öyküsü içerisinden sürdürülebilir kalkınmanın bütün boyutlarını işaret eden bileşenler ve işlemler belirtmeleridir. Neredeyse bütün katılımcılar bu beceride en üst düzeye ulaşmışlardır. Ancak bulgular detaylı incelendiğinde katılımcılar tarafından listelenen bileşen ve işlemler arasında çevre boyutuyla ilgili olanların sayıca öne çıktığı görülmektedir.

"Sistem içerisindeki bileşenler ve işlemler arasındaki ilişkileri tanımlamak" (SDB 2) ölçülen ikinci sistemsel düşünme becerisidir. Sistem içerisindeki bileşen ve işlemler bu çalışmada çevresel, ekonomik ve sosyal olarak sınıflandırılmıştır. Aynı zamanda bu sistemsel düşünme becerisi Ben-Zvi Assaraf ve Orion (2005)'in tanımladığı sistemsel düşünme becerilerinden biridir. Araştırmacılar, öğrencilerle yaptıkları çalışmada öğrencilerin açık bir şekilde bağlantılı olan bileşenler arasındaki ilişkiyi kolayca tanımladıklarını gözlemlemişlerdir. Bununla birlikte, öğrencilerin farklı boyutlardaki bileşen ve

işlemler arasında ilişki kurmakta zorlandığı bu sistemsel düşünme becerisini ölçen diğer araştırmacılar tarafından ifade edilmiştir (Hmelo- Silver & Pfeffer, 2004; Raved & Yarden, 2014; Shepardson vd., 2014). Benzer sonuçlarla öğretmen ve öğretmen adaylarıyla yapılan araştırmalarda da karşılaşılmaktadır (Karaarslan, 2016; Lee, 2015). Burada sunulmakta olan araştırmada da benzer bir sonuç sergilenmektedir. Katılımcıların bulduğu etkileşimlerin büyük çoğunluğu çevresel bileşenler arasında kurulmuştur. Öte yandan sürdürülebilir kalkınmanın farklı boyutlarına ait bileşenler arasında kurulan ilişkilerin sınırlı sayıda olduğu gözlemlenmiştir. Bu sistemsel düşünme becerisi için yalnızca bir katılımcı üçüncü düzeye ulaşabilmiştir. Bu bulgulara dayanarak, SDB 1'de araştırılan, sistem içerisindeki farklı bileşenleri bulabilme becerisinin SDB 2'de farklı bileşen ve işlemler arasında ilişki kurabilme becerisi için bir öncelik olduğu çıkarımı yapılabilir.

Bu araştırmadaki üçüncü sistemsel düşünme becerisi ise "sistem hakkında genelleme yapabilmek" olarak isimlendirilmiştir. Bir kavramın ana fikri başarılı bir şekilde özümsendiğinde, kişilerin bu ana fikri farklı ortamlara da aktarabilmesi beklenir (Goldstone & Wilensky, 2008). Ancak bu aktarımın yapılabilmesi için kavram içerisindeki bileşenlerin ezberlenmeden anlaşılması gerekir (Lyons, 2014). Sistem hakkında genelleme yapabilme becerisi katılımcıların bu araştırmada en düşük düzeylerde derecelendiği becerilerden biri olarak gözer çarpmaktadır. Elde edilen bulgular öğretmen adaylarının yoğunlukla çevresel boyut üzerine genelleme yaptığını göstermiştir. Üç katılımcı genellemelerine ekonomik boyutu eklerken sosyal boyut bütün katılımcılar tarafından göz ardı edilmiştir. Bulgular değerlendirildiğinde, bu becerinin karmaşık bir beceri olarak değerlendirilebileceği sonucuna varılmıştır.

"Sistem içerisindeki gizli boyutları fark edebilmek" (SBD 4) katılımcıların yüksek başarı gösterdikleri bir diğer sistemsel düşünme becerisi olarak bulunmuştur. Sürdürülebilir kalkınma kapsamında bu beceri sistemin

içerisindeki çevresel, sosyal ve ekonomik boyutlardan, iklim değişikliği, nüfus artışı, yoksulluk gibi farklı bileşenleri fark etmeyi sağlayan bir beceri olarak nitelendirilmiştir (Karaarslan, 2016). Sistem içerisinde doğrudan işaret edilmeyen bileşenleri fark edebilmek alanda yapılan geçmiş çalışmalarda zorlayıcı ve karmaşık bir sistemsel düşünme becerisi olarak belirtilmiştir (Golick vd., 2017; Lee, 2015; Sibley vd., 2007). Ancak katılımcıların deneyimsel bilgilerinin yüksek olması ve sistem üzerinde derinlemesine sorgulama yapıldığında bu becerinin geliştiği gözlemlenmiştir (Ben-Zvi Assaraf & Orion, 2005; Eilam, 2012). Bu tezde gerçek yaşam öyküsü kullanımı sayesinde, katılımcıların konu hakkında detaylı bir tartışma yürütebilme imkânı elde etmesinin gizli bileşenlerin tespit edilmesini kolaylaştırdığı fark edilmiştir.

"Sistemin döngüsel yapısını tanımlamak" (SDB 5) bu çalışmada konu edilen beşinci sistemsel düşünme becerisidir. Öğrencilerle yapılan araştırmalarda sistemin farklı boyutları arasındaki döngüsel ilişkilerin fark edilmesinde öğrencilerin zorlandığını fark edilmiştir (Hmelo- Silver vd., 2007, Shepardson vd. 2014). Ancak döngüsel ilişkilerle yaşamın her alanında karşılaşılabilir (Ben-Zvi Assaraf & Orion, 2005). Sürdürülebilir kalkınma da çevresel, ekonomik ve sosyal boyutlarıyla birlikte döngüsel bir yapı oluşturmaktadır. Ancak bu araştırmadaki öğretmen adayları döngüsel ilişkilerde de çoğunlukla çevresel boyuta odaklanmışlardır. Bu bulgu döngüsel düşünmenin kazanılması zor bir beceri olduğunu göstermiştir. Fakat bu becerinin edinilmesi sistemin bir bütün olarak ele alınabilmesi ve sistem içerisindeki değişikliklerin sonuçlarının anlaşılabilmesi için oldukça önemlidir.

Bu araştırmadaki altıncı sistemsel düşünme becerisi ise "sistem içerisindeki etkileşimlerin gelecek etkilerini fark edebilmek" (SDB 6) olarak tanımlanmıştır. Bu beceri geçmiş, gelecek ve şimdiki zamanda yapılan her etkinliğin birbiriyle bağlantılı olduğunu anlamayı içermektedir (Ben-Zvi Assaraf & Orion, 2005). Karaarslan (2016), bu beceriyi sürdürülebilir kalkınma düzleminde değerlendirmiş ve bu beceriyi edinmenin bu kavramla ilişkili

problemlerin anlaşılıp, bu problemlere çözüm üretilmesindeki önemini vurgulamıştır. Bu araştırmada, diğer becerilerde gözlemlenen bulgularla uyumlu olarak çevresel boyutla ilgili gelecek tahminler öne çıkmaktadır. Buna karşılık, çevredeki değişimlerin gelecekteki sonuçlarının ekonomik ve sosyal boyutlarda da değerlendirilmesi sürdürülebilir kalkınma hakkındaki farkındalığın gelişmesi açısından önem taşımaktır.

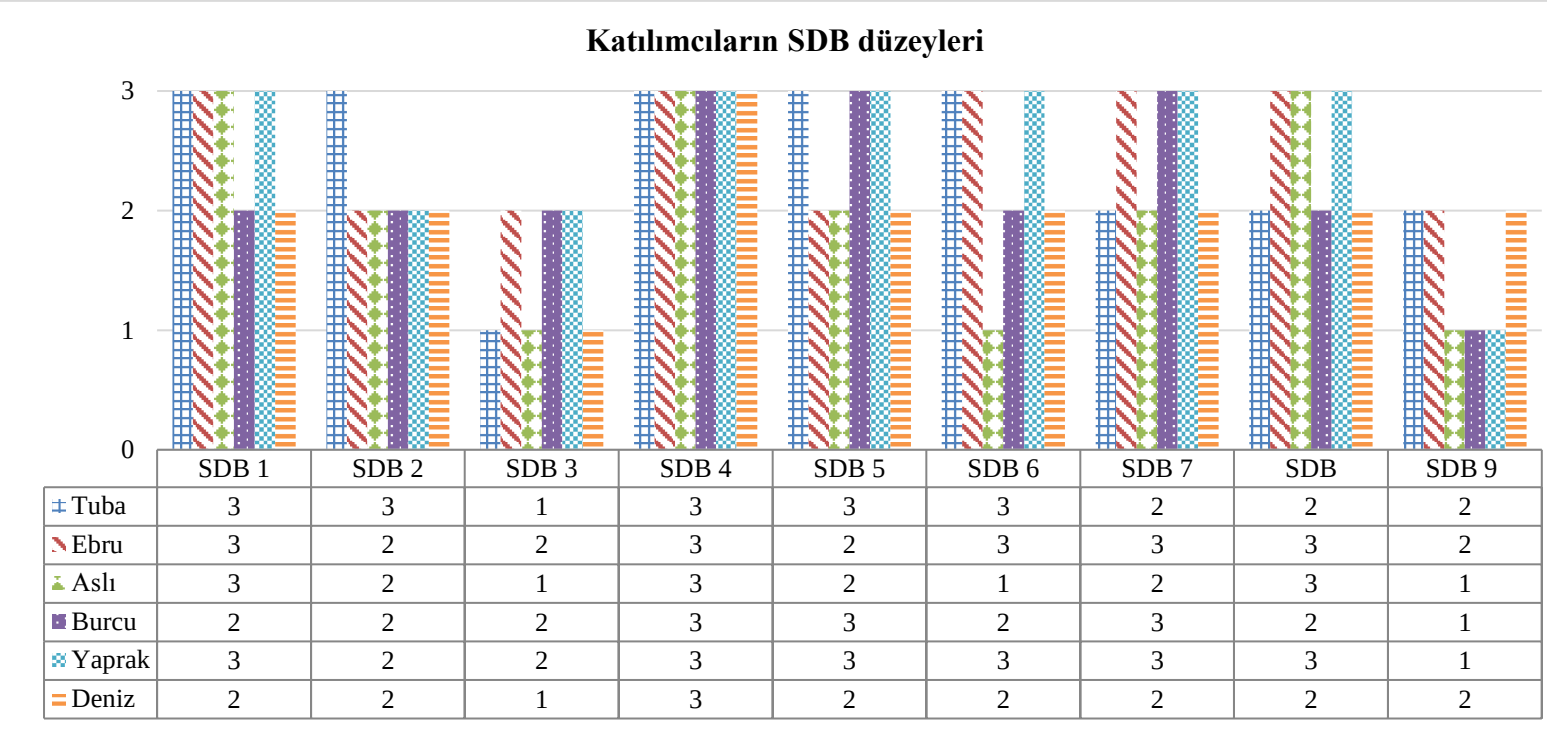
Bu araştırmada değerlendirilen yedinci sistemsel düşünme becerisi olan "diğer insanlar ve canlılarla empati yapabilmek" (SDB 7) Karaarslan (2016)'nın çalışmasında "diğer insanlarla empati yapabilmek" ve "diğer canlılarla empati yapabilmek" olarak iki ayrı beceride ele alınmıştır. Dünya bütün insanlar ve canlılarla birlikte bir bütün olarak değerlendirilmelidir. Empati yapabilmek bu unsurun anlaşılmasında önemli bir basamak olarak belirtilmiştir (Karaarslan, 2016). Bu araştırmada da empati yapabilmenin katılımcılarda olumlu bir tutum oluşturduğu gözlemlenmiştir. Farklı kişilerin bakış açılarını göz önünde bulundurmak katılımcıların herkes için faydalı olabilecek çözümler üretmelerine yardımcı olmaktadır. Ek olarak, diğer canlılarla empati yapabilen katılımcıların ekoloji merkezci düşünmeyi benimsedikleri gözlemlenmiştir.

"Sistem içerisinde kendi sorumluluğunun farkına varabilmek" (SDB 8) de bu çalışmadaki sekizinci sistemsel düşünme becerisidir. Kendi sorumluluğunun farkına varabilmek küresel bir vatandaş olabilmenin önemli bir bileşeni olarak belirtilmektedir (Choi, Lee, Shin, Kim & Krajcik, 2011). Karaarslan (2016) bu beceriyi kişisel eylemlerin doğal olaylarda ve başka insanların yaşamları üzerinde etkileri olabileceği hakkında farkındalık kazanmayı sağladığını belirtmektedir. Araştırmacı ayrıca eğitimde sürdürülebilir kalkınmayı gerçekleştirebilecek öğretmenlerin öğrencilerine çevresel, sosyal ve ahlaki değerleri aktarabilen bireyler olduklarını açıklamıştır. Bunun yanı sıra sorumluluk alabilmek, bilinçli bir vatandaş olmak için gerekli kişisel ve sosyal bütünlüğü oluşturmak için ihtiyaç duyulan önemli bir beceri olarak öne çıkmaktadır (Zoller, 2011). Bu çalışmada katılımcıların sorumluluk alma

becerisi bir gerçek yaşam öyküsü kullanılarak ölçülmüştür. Gerçek yaşam öyküsü öğretmen adaylarının sürdürülebilir kalkınmayla ilgili bir konuyla kişisel bağ kurmasını sağlamıştır. Bulgular, öykü hakkında bir sorumluluk alabilen katılımcıların bu yönde bir bakış açısı ve alışkanlık sahibi olduklarını göstermiştir.

Katılımcıların çoğunlukla düşük düzeyde değerlendirildikleri bir diğer sistemsel düşünme becerisi ise "bir mekân algısı geliştirebilmek" (SDB 9) olarak bulunmuştur. Bu beceride katılımcıların çoğunlukla birinci düzeyde sıralandıkları görülmüştür. Bir mekânı bu farklı boyutlar çerçevesinde değerlendirmek Karaarslan (2016) tarafından da karmaşık bir sistemsel düşünme becerisi olarak tanımlanmıştır. Bu beceride bir mekanla ilgili dört farklı boyut tanımlanmıştır: çevresel, psikolojik, sosyokültürel ve politik-ekonomik. Burada anlatılan çalışma sırasında da katılımcılardan Kızılırmak havzasına dair oluşturdukları mekânsal algıyı tasvir etmeleri beklenmiştir. Fakat değerlendirme sonucunda katılımcıların yine çevresel boyuta odaklandıkları gözlemlenmiştir.

Bütün bunlara ek olarak, görüşme sırasında katılımcıların geçmiş deneyimlerinin gerçek yaşam öyküsünü yorumlamalarında etkili oldukları fark edilmiştir. Doğada daha fazla vakit geçirme ve gözlem yapma şansı bulan katılımcıların çevre boyutuyla ilgili daha fazla yorum yaptıkları görülmüştür. Görüşme sırasında bütün katılımcılardan sistem hakkında bir tanım yapmaları ve örnek vermeleri istenmiştir. Katılımcıların sistem hakkındaki tanımlarının anlamlı ve sistemsel düşünmeye uygun olduğu gözlemlenmiştir. Ayrıca verilen örnekler de değerlendirilerek, bu araştırmada konu edilen öğretmen adaylarının sistem kavramı hakkında belirgin bir kavrayışları olduğu gözlemlenmiştir. Bu durum sistemsel düşünme becerilerinin uygun bir uygulama yöntemiyle gelişmeye açık olduğuna dair ipucu vermiştir.




| | SDB 1 | SDB 2 | SDB 3 | SDB 4 | SDB 5 | SDB 6 | SDB 7 | SDB | SDB 9 |
|---|---|---|---|---|---|---|---|---|---|
| Tuba | 3 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 2 |
| Ebru | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 2 |
| Aslı | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 1 |
| Burcu | 2 | 2 | 2 | 3 | 3 | 2 | 3 | 2 | 1 |
| Yaprak | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 1 |
| Deniz | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 2 | 2 |

*Şekil 1: Katılımcıların genel SDB düzeyleri*

## 2. Fen Bilimleri Öğretmen Adaylarının Sürdürülebilir Kalkınma Kavramına Dair Anlayışları

Sürdürülebilir kalkınma içerisinde barındırdığı farklı boyutlar ve bu boyutlar arasındaki ilişkiler sebebiyle bütünleşik bir sistem oluşturmaktadır (Sleurs, 2008). Öğretmenlerin sürdürülebilir kalkınma konusunda somut bir kavrayışa sahip olmalarıysa sosyal ve çevresel problemlerin çözümünde önemli bir rol oynamaktadır (Nolet, 2009). Öte yandan çalışmalar öğretmenlerin ve öğretmen adaylarının bu konuda yetersiz bir bilgi birikimine sahip olduklarını ve sürdürülebilir kalkınmayı yalnızca çevre boyutuyla ele aldıklarını göstermektedir (Mills & Tomas, 2013; Sagdic, 2013). Bu çalışma sırasında yapılan görüşmeler değerlendirildiğinde, çalışmaya katılan öğretmen adaylarının sürdürülebilir kalkınmanın çevresel boyutuna daha fazla vurgu yaptığı görülmüştür. Sistem içerisindeki döngüsel ilişkileri açıklarken (SDB 5) yoğun olarak doğal döngülerden bahsedildiği fark edilmiştir. Dahası, görüşme sırasında okudukları gerçek yaşam öyküsü ve sürdürülebilir kalkınma hakkında bir ilişki kurmaları istendiğinde katılımcıların yarısının sürdürülebilir kalkınmayı doğrudan çevre ile ilişkilendirdiği gözlemlenmiştir.

Sonuç olarak bu çalışmada sürdürülebilir kalkınma hakkında elde edilen bulgular, fen bilimleri öğretmen adaylarının sürdürülebilir kalkınma hakkında yetersiz kavramsal bilgiye sahip olduklarına dair ipuçları vermiştir.

### 3. Sistemsel Düşünme Becerilerinin Değerlendirilmesinde Gerçek Yaşam Öykülerinin Kullanımı

Gerçek yaşam öyküleri sürdürülebilir kalkınma ve çevre eğitiminde sıkça kullanılan bir araç olarak öne çıkmaktadır. Tartışılan problemlerin geçmişi üzerine ayrıntılı bilgi sağlaması, bu problemlere dair çözüm bulunmasında kişilere daha geniş bir bakış açısı kazandırmaktadır (Kortenkampand & Moore, 2011). Dahası, çevre ile ilgili konularda gerçek öykülerinin problemin karmaşık yapısını öne çıkarmaya yardımcı olduğu ve gerçek problemler üzerine tartışmanın problem çözme becerilerini harekete geçirdiği öne sürülmüştür (Remington- Doucette, Connell, Armstrong, & Musgrove, 2013; Tuncay, 2010). Sürdürülebilir kalkınma ve sistemsel düşünme bağlamında da gerçek yaşam öykülerinin kullanışlı bir araç olduğu belirtilmiştir (Karaarslan, 2016).

Bu çalışmada fen bilimleri öğretmen adaylarının sistemsel düşünme becerileri sürdürülebilir kalkınmanın farklı boyutlarını işaret eden bir gerçek yaşam öyküsü kullanılarak değerlendirilmiştir. Katılımcıların konuyu kolaylıkla benimsemeleri ve örtük anlamlı görüşme soruları sayesinde detaylı bir bakış açısı sağlamıştır. Görüşme sırasında konuyla ilişkili kişisel deneyimlerin paylaşılması, bir gerçek yaşam öyküsünü yorumlamanın katılımcıları detaylı düşünmeye sevk ettiğini çıkarımına ulaşılabilir. Bu tezde gerçek yaşam öyküsü kullanılarak yapılan değerlendirme, tezde tanımlanan sistemsel düşünme becerileri üzerine yapılan diğer çalışmalarla tutarlılık göstermiştir. Bir başka deyişle, gerçek yaşam öykülerinin sistemsel düşünme becerilerinin ölçülmesinde kullanılabileceği sonucuna ulaşılmıştır.

## ÖNERİLER

Bu çalışma sistemsel düşünme becerilerini eğitim alanında yorumlamayı amaçlayan araştırmacılar için bir öngörü oluşturmayı amaçlamaktadır. Öncelikle bu çalışmada yerel bir haberi konu alan bir gerçek yaşam öyküsü kullanılmıştır. Gelecek araştırmalarda farklı bir konu içeren gerçek yaşam ölçüleri incelenebilir. Örneğin katılımcıların küresel ve yerel kaynaklı gerçek yaşam öyküleriyle ilgili yanıtları karşılaştırılabilir. Ayrıca, gerçek yaşam öykülerinin sistemsel düşünme becerilerinin değerlendirmesinde kullanımı, bu çalışmada kullanılan Ben-Zvi Assaraf ve Orion (2005) ve Karaarslan (2016)'nın tanımladığı sistemsel düşünme becerilerinden farklı sistemsel düşünme becerileri ve çerçeve kullanarak da test edilebilir. Bu çalışmada elde edilen veriler sistemsel düşünme becerilerinin sürdürülebilir kalkınma kavramını anlama ve bu kavramla ilişkili problemlere çözüm sunma açısından önemini vurgulamaktadır. Sistemsel düşünme becerilerinin disiplinler arası tabiatı sebebiyle, bu tez sadece fen bilimleri eğitiminde değil farklı disiplinlerdeki program geliştirme uzmanlarına da kaynak sağlamaktadır.

## APPENDIX E.

## TEZ FOTOKOPİSİ İZİN FORMU

**ENSTİTÜ**

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ■

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

**YAZARIN**

Soyadı: Öztaş
Adı: Melike
Bölümü: İlköğretim

**TEZİN ADI** (İngilizce): Assessing Pre-Service Science Teachers' Systems Thinking Skills Using Real Life Scenarios

**TEZİN TÜRÜ :** Yüksek Lisans ■ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ☐
ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir.

3. Tezim bir (1) yıl süreyle erişime kapalı olsun. ■

**TEZİN KÜTÜPHANEYE TESLİM TARİHİ:**