SCIENCE TEACHERS AS ESD EDUCATORS: AN OUTDOOR ESD MODEL FOR DEVELOPING SYSTEMS THINKING SKILLS

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ABSTRACT

SCIENCE TEACHERS AS ESD EDUCATORS: AN OUTDOOR ESD MODEL FOR DEVELOPING SYSTEMS THINKING SKILLS

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The main purpose of this thesis is to explore how science teachers could become Education for Sustainable Development (ESD) educators. The study was conducted in five stages which are: gap analysis, developing systems thinking skills measurement tools, designing an outdoor ESD course, conducting a pilot study, and conducting the main study. Through gap analysis, systems thinking was found out to be a required competence for science teachers to become ESD educators. In the second stage, twelve systems thinking skills were determined and a series of qualitative data collection tools were developed and adapted. The third stage included designing an outdoor ESD course to develop the pre-determined systems thinking skills of pre-service science teachers. The pilot study in the fourth stage was carried out for the purposes of assessing the validity and the reliability of the tools, measuring the current state of systems thinking skills of the pre-service science teachers, and piloting the outdoor ESD course. In the final stage, the main study was conducted to develop systems thinking skills of eight pre-service science teachers through the outdoor ESD course.

The results revealed that outdoor ESD course holds an important potential to develop systems thinking skills of pre-service science teachers. Development of the skills were found to be dependent on the individual differences and complexity among the skills. In conclusion, this study aims to make unique contributions to both science education and ESD literature by offering an outdoor ESD model to educate pre-service science teachers for a sustainable future.

Keywords: Education for Sustainable Development, Pre-Service Science Teachers, Outdoor Education, Systems Thinking

ÖZ

SÜRDÜRÜLEBİLİRLİK İÇİN EĞİTİM EĞİTMENİ OLARAK FEN BİLGİSİ ÖĞRETMENLERİ: SİSTEMSEL DÜŞÜNME BECERİLERİNİ GELİŞTİRMEK İÇİN AÇIK ALANDA SÜRDÜRÜLEBİLİRLİK İÇİN EĞİTİM MODELİ

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Bu çalışmanın temel amacı fen bilgisi öğretmenlerinin sürdürülebilirlik için eğitim (SiE) eğitmeni olabilmeleri için uygun eğitim modelini ve etkisini nitel bir araştırma yöntemiyle araştırmaktır. Bu çalışma beş aşamadan oluşmaktadır. Bunlar, fark analizi, sistemsel düşünce becerilerinin ölçülmesi için ölçeklerin geliştirilmesi, açık alanda SiE dersinin tasarlanması, pilot çalışma ve ana çalışmadır. İlk olarak fark analizi yöntemi ile sistemsel düşünme becerisinin fen bilgisi öğretmenlerinin SiE eğitmeni olabilmeleri için gerekli olduğu belirlenmiştir. İkinci aşamada fen eğitimi ve SiE alanında on iki sistemsel düşünme becerileri tanımlanmış ve bu becerilerin ölçülmesi amacı ile nitel ölçme araçları geliştirilmiştir. Üçüncü aşamada ise fen bilgisi aday öğretmenlerinin sistemsel düşünme becerilerinin geliştirilmesi amacı ile açık alanda SiE dersi tasarlanmıştır. Çalışmanın pilot denemesinin yapıldığı dördüncü aşamada daha önce geliştirilen ölçme araçları test edilmiş ve fen bilgisi öğretmenlerinin mevcut sistemsel düşünme becerileri belirlenmiş ve açık alanda SiE dersinin pilot uygulaması gerçekleştirilmiştir. Son olarak, ana çalışma sekiz fen bilgisi öğretmen adayının sistemsel düşünme becerilerini açık alanda SiE dersiyle geliştirmek amacıyla uygulanmıştır.

Sonuçlar fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin açık alanda SiE dersiyle geliştirilebileceğini göstermiştir. Buna ek olarak, sistemsel düşünme becerilerinin gelişiminin bireysel farklılıklara ve beceriler arasında karmaşık ilişkilere de bağlı olduğu bulunmuştur. Sonuç olarak, bu çalışma sürdürülebilir bir gelecek için aday fen bilgisi öğretmenlerinin eğitilmesinde açık alanda SiE modelini önermektedir. Bu sayede çalışmanın hem fen eğitimi hem de SiE alan yazınına önemli katkılar sunması planlanmaktadır.

Anahtar Kelimeler: Sürdürülebilirlik için Eğitim, Fen Bilgisi Öğretmen Adayları, Açık Alanda Eğitim, Sistemsel Düşünme

To Mother Earth

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LIST OF ABBREVIATIONS

ESD	Education for Sustainable Development
PST	Pre-service Science Teacher
SE	Science Education
EE	Environmental Education
STS	Systems Thinking Skills
NRC	National Research Council
MoNE	Ministry of National Education
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational Scientific and Cultural Organization
OECD	Organization for Economic Corporation and Development
UN	United Nations
UNCED	United Nations Conference on Environment and Development

CHAPTER I

INTRODUCTION

Since 1950, significant changes have occurred on the earth and the earth has been driven to a new age called as Anthropocene, denoting domination of the earth by human activities (Brito & Smith, 2012). In a more cynical point of view, human activities are pushing the earth to the sixth mass extinction or Anthropocene extinction (Kolbert, 2014). On the global scale, rapid increase in the concentrations of CO_2 and other greenhouse gases in the atmosphere that result from human activities such as burning fossil fuels and industrial agriculture brings out unpredictable consequences (Feldman & Nation, 2015). Among these, food shortage, energy crisis and global climate change are the major ones that humanity faces today, and as Orr (2004, p. 9) remarked “we are all ignorant about the changes in the world”. Most of the researchers posit that one of the significant ways to be engaged with these changes and challenges to create a sustainable world is education (Feldman & Nation, 2015).

The roots of Environmental Education (EE) appear in the historical documents of Belgrade Charter (UNESCO, 1976) and Tbilisi Declaration (UNESCO-UNEP, 1977). The main goal of EE in these documents was described as protecting the environment and reducing the human impact. A decade after Tbilisi and Belgrade Charter, Brutland Report (UN, 1987) and United Nations Conference on Environment and Development held in Rio (UNCED, 1992), the attention was drawn to the social, economic and political aspects of the issues. The overall intent has shifted from environmental protection for meeting needs of the humanity to meeting the needs of environment and society (McKeown & Hopkins, 2003).

That is to say, environment and development concepts have been brought together since Rio conference in 1992 (Gough, 1997). Thus, with the core shift from Tbilisi to Rio, EE has started to evolve to Education for sustainable development (ESD) (McKeown & Hopkins, 2003) and ESD has been built on EE (Marcinkowski, 2010). Chapter 36 of Agenda 21 titled as "Promoting Education, Public Awareness and Training" pointed out education as a vital factor to promote sustainable development (UNESCO, 2005b). Thus, the seed of ESD was planted in the Agenda 21, which was a landmark publication of UNCED (1992). Although there is not a single definition or a single interpretation, UNESCO (2013) defined ESD as "empowering everyone to make informed decisions for environmental integrity, economic viability and a just society for present and future generations while respecting cultural diversity". ESD is a broad and holistic concept that does not only deal with integrating sustainability issues to existing curricula and programs, but it is also mainly concerned with the transformation of education system to reorient societies for sustainable development (UNESCO, 2014). Therefore, ESD engages with all levels of education from early childhood to higher education and every discipline from art, history to science and mathematics could provide knowledge, skills, and values to implement ESD and create an interdisciplinary connection of ESD (McKeown and Hopkins, 2003).

Science education (SE) and ESD have a historical link. In 1970s, when the EE (earlier form of ESD) has come into the agenda there was a widespread belief in the society that environmental problems could be solved through further scientific and technological developments (Gough, 2008). These scientific and technological developments influenced the vision of SE through the years (e.g., Carter, 2008; Deboer, 2000). Since 1950s, the main goal of SE has been to grow scientifically literate citizens, and today it is argued that the meaning of scientific literacy should be expanded to meet the needs of the 21st century (Choi, Lee, Shin, Kim & Krajcik 2011). Scientific knowledge together with technology brought enormous changes in human life like traveling long distances by plane at cheaper costs, but it also brought declining oil supplies and an increase in the amount of greenhouse gases (Levinson, 2010). In other words, scientific and technological developments brought ethical and moral concerns and resulted in several environmental problems such as climate change (Choi, et al., 2011). In order to deal with these kinds of problems, we need to consider questions such as what might be the effects of nano-scale products on the environment both locally and globally, how can we create a sustainable planet while considering future generations' energy need, and how could we could increase the quality of our life while decreasing environmental problems (e.g., Choi et al., 2011; Feldman & Nation, 2015). These sustainability problems are complex and interconnected; therefore, SE could emphasize the increasing complexity of these local and global problems (Sterling, 2010), considering the social, economic and environmental aspects of sustainability to create a more sustainable planet (Feldman & Nation, 2015).

Considering the current rapid developments in science, technology and engineering, the ethical and moral concerns, and the need to emphasize sustainability issues, a number of SE researchers have suggested a reconceptualization of SE (e.g., Carter, 2008; Colucci-Gray, Perazzone, Dodman & Camino, 2013; Feldman & Nation, 2015; Gough, 2008). Carter (2008), for example, argued that the purpose of SE in the 21st century should be to help students make critical judgments about science and increase their engagement to work for a more socially just, equitable and sustainable world. Further, several researchers (e.g., Choi et al., 2011; Hodson, 2011 (as cited in McFarlane, 2011) asserted that scientific literacy should be redefined by considering the needs of the society and to ensure a sustainable future. For these reasons, the collaboration between SE and ESD is needed in order to help individuals understand how sustainability issues influence different segments of the society, to explore three pillars of sustainability (economic, social and environmental) (Feldman & Nation, 2015), and to increase students' interest and motivation to take action in social and global problems (Tytler, 2007). Today, there are increasingly more efforts to integrate sustainability into SE through a variety of ways such as Science-Technology-Society (STS), Science-Technology, Environment and Society (STES), science, technology, engineering and mathematics (STEM) or environment, science, technology, engineering and mathematics (E-STEM) (e.g., NRC, 2012; NAAEE, 2016). These are important developments in SE research.

SE as a discipline should include sustainability topics to develop students' sustainability perspectives (e.g., Feldman & Nation, 2015) and educate them as responsible citizens to create a sustainable future (Stratton, Hagevik, Feldman & Bloom, 2015). Therefore, preparation of science teachers for a sustainable future is an urgent need. Science teachers need to be aware of their individual and collective actions, and the possible ways they could contribute to creating a sustainable future (Tippins, Pate, Britton & Ammons, 2015). Science teachers should also be prepared as sustainability literate, globally minded citizens (Carney, 2011; Foley, Archambault & Warren, 2015), and they should have necessary knowledge and skills to grow their future students who could act for sustainability of the earth (Stratton et al., 2015). Therefore, there is a need to educate science teachers as ESD competent educators who could understand complexity and interconnectedness of the current problems and educate young learners as globally responsive and environmentally sustainable future citizens.

1.1 Teacher Education for ESD

Teacher education for ESD has been reported to be one of the important challenges for today and the future. Teachers are key agents in ESD as they could shape future generations' abilities to create a sustainable world (UNESCO, 2014). Therefore, to create a sustainable society, all teachers, educators, leaders and decision makers should have required competencies at all levels of education (UNECE, 2011). This thesis specifically focused on how to prepare science teachers as ESD educators. For this reason, required competencies for science teachers and ESD educators were investigated. In the literature, the term competency is accepted as a critical landmark in terms of teaching and learning of sustainability (Wals, 2010; Wiek, Withycombe & Redman, 2011; UNECE, 2011). In the literature, competency has been defined in various ways, and a common definition for competency is performing a task or an activity effectively (De Bueger (1996) (as cited in Naumescu, 2008). In the sustainability literature, competency is defined from a broader perspective including several dimensions such as knowledge, skills, willingness, attitudes (e.g., Sleurs, 2008; Stratchan, 2012; Weinerts, 2001 (as cited in Adombent & Hoffmann, 2013). Weinerts (2001) defined competency as “positive combination of knowledge, ability and willingness in the availability of the individual to cope successfully and responsibly with changing situations”. Moreover, Naumescu (2008) defined competency as a more complex term that “the performance of the tasks, the management of the tasks, the ability to respond to irregularities, the capacity to deal with complexities, taking responsibility, working with others, attitudes to new tasks and new situations”. Based on the ESD literature, in this thesis, competency is defined as a complex, multi-structured term as including knowledge, intellectual and pedagogical skills, dispositions and both cognitive and affective aspects (e.g., Sleurs, 2008; Strachan, 2012; UNECE, 2011). As sustainability problems are complex and interrelated, specific key competencies are needed to be able to solve these problems (Wiek, Withycombe & Redman, 2011). All teachers and educators should be equipped with required competencies in order to engage in ESD. In order to develop teachers’ professional development for ESD, UNESCO (2005b) identified several guidelines and recommendations. Accordingly, the five goals of ESD are: environmental stewardship, social equity, justice and quality of life for all generations. Also, UNESCO (2004, 2005b, and 2006) recommended new models of professional development for ESD educators that included essential skills, cross-cultural approaches and action based learning models for pre-service and in-service teachers.

More recently, there are also attempts in higher education institutions to integrate sustainability into teacher education programs (Stevenson, Ferreria, Evans & Davis, 2015). For instance, Washington State asserted, in a report prepared on teacher education requirements (content, methodology and competencies), that teachers need to prepare students as responsible citizens for a sustainable world (Washington State OSPI, 2008). Further, required ESD competencies for teachers have been determined in several research papers and policy documents (e.g., Sleurs, 2008; UNECE, 2011). In addition, United Nations Economic Commission for Europe (UNECE, 2011) made a call for transforming education towards sustainable development to shape abilities of future generations in order to create sustainable societies. It also declared that teachers at all sectors of education should have core competencies to integrate ESD into their programs (UNECE, 2011). These policy documents and research papers also have implications for science teacher education. Several key documents identified basic competencies for science teachers such as subject matter knowledge, pedagogical knowledge and skills (e.g., Nezvalova, 2007; NSTA, 2012). Yet, there are lack of explanations related to ESD competencies such as emphasizing the relationship among environment, society and economy, considering the relationship among past, present and future, understanding different groups, cultures (building empathic relationship) and systems thinking. However, recently the new SE framework prepared by National Research Council (NRC, 2012) included several items that are relevant to characteristics of ESD. NRC (2012) addressed interrelationship among science, engineering and technology, developing students' understanding of complex systems and systems thinking in engineering projects. In SE and science teacher education field there is a tendency to develop students' and teachers' understanding of complex systems and developing an integrated, holistic way of understanding. Therefore, developing science teachers' ESD competencies holds an important base. As Stevenson et al (2015) mentioned, ESD provides a wider scope from environmental to social, economic, cultural, political factors and emphasize complex relationship among these factors as far as global challenges such as climate change, biodiversity loss (Wals, Brody, Dillion, & Stevenson, 2014). In other words, ESD refers to a holistic approach rather than a reductionist approach which are generally common in traditional education systems, and it focuses on sustainability problems at a systemic level (Sterling, 2001; Tilbury, Coleman & Garlick, 2005). Therefore, teaching complex relationships and sustainability issues need complex understanding, willingness and capacity (Stevenson et al., 2015), that sets a base for the competencies of ESD educators implying integrative approaches and systems thinking (UNECE, 2011). Especially, systems thinking is seen as a key feature in the ESD and sustainability competencies documents and papers (e.g., UNECE, 2011; Sleurs, 2008; Wiek et al., 2011) and as a core competency for ESD educators (Strachan, 2012). Accordingly, considering ESD as an undeniable need of the 21st century, there is a need for developing science teachers' competencies to understand the complex relationships among social, cultural, economic and environmental systems and sustainability issues, in particular, science teachers are expected to gain systems thinking skills (STS).

1.2 Systems Thinking Skills: Theoretical Framework

The complexity and interconnectedness of today's problems such as climate change, energy, and food security requires a radical shift in our way of thinking. A shift from reductionist thinking (thinking in isolation) towards systems thinking is needed for building a sustainable future (Capra & Luisi, 2014; Sleurs, 2008). System is defined in the literature in different ways, but giving the same idea. System refers to interconnectedness among the elements of a system and an integrated whole that cannot be reduced to smaller parts (e.g., Capra, 1993; Meadow, 2008). For instance, a system could be a set of things such as a city, a school, a family, a forest, an ecosystem etc. (Sterling, Maiteny, Irving & Salter, 2005). Also, it is essential for individuals to understand a system and its components. For instance, to be able to understand climate change, first, students should understand climate as a system (Shepardson, Niyogi, Roychoudhury, & Hirsch, 2012). In essence, in order to understand complex systems, components, interactions and to see the bigger picture, a new way of thinking is required (Capra & Luisi, 2014; Shepardson et al., 2014). This new way of thinking is related to thinking in relationships, in contexts and patterns and it is, in general, called systems thinking (Capra & Luisi, 2014).

Systems thinking emerged in the 20th century as a reaction to reductionist, non-linear thinking (Capra, 1982; Capra & Luisi, 2014). When the history of western science in the 16th and 17th century was examined, the common way of thinking was related to Newtonian-Cartesian worldview suggested that universe worked as a machine, according to mechanical laws (Capra & Luisi, 2014). Yet, during the scientific revolutions in the 19th and 20th century such as emergence of evolution theory, organismic biology helped to reveal a new way of thinking. Therefore, Newtonian-Cartesian mechanistic view lost its effect through new scientific revolutions. In other words, the universe was accepted to work more complex than Descartes and Newton had explained (Capra & Luisi, 2014). Systems thinking arouse during these times, especially in biology and ecology disciplines. For instance, some biologists pointed out that living systems could be understood as an integrated whole without reducing to smaller parts (Capra & Luisi, 2014). Later, systems thinking became popular in other disciplines such as psychology, philosophy, physics, engineering and economy (Sleurs, 2008). Systems thinking has been studied broadly in engineering and business fields as well. The researchers in these fields (e.g., Senge, 1990; Frank, 2000; Booth-Sweeney & Sterman, 2000) defined systems thinking as a higher order thinking that includes cognitive abilities like problem solving, scientific reasoning, understanding dynamic process and complexity. According to Senge (1990), systems thinking is required in science, technology and everyday life. More recently, systems thinking drew attention of educators and has been considered as a critical approach in education (Hmelo, Holton & Kolodner, 2000). Especially, in SE context a series of studies were conducted by several SE researchers (Assaraf & Orion, 2005, 2010a, 2010b; Batzri, Assaraf, Cohen & Orion, 2015; Keynan, Assaraf & Goldman, 2014). More specifically, these researchers dealt with systems thinking in the earth systems science context. Assaraf and Orion (2005), for example, defined systems thinking in earth systems context as including eight emergent characteristics such as the ability to identify components of a system, relationships, and hidden dimensions in a system, cycling nature of the system and temporal thinking. The authors' description of systems thinking also included cognitive components, and it specifically focused on understanding complex structure of the natural systems. Systems thinking has also been emphasized in ESD context and even more, it has been considered as a central theme of ESD. In the ESD context, systems thinking has been defined in various ways but they all had same meaning. Tilbury and Cooke (2005) described systems thinking as a type of thinking methodology, a critical understanding of complex natural systems, and their functions and interrelationships. Nolet (2009) identified systems thinking as one of the components of sustainability literacy and described systems thinking as including not only relationships among species and nature and but also connections among social, economic and ecological systems. Capra (2005) and Sterling et al. (2005) defined systems thinking in terms connectedness, understanding relationships, patterns and context. According to Capra (2005) systems thinking is a shift of perception, a new way of thinking that is needed for building sustainable societies. Therefore, systems thinking, in general, has been accepted as a key competency for ESD (e.g., Sleurs, 2008; UNECE, 2011). The literature provided various definitions for systems thinking yet, they all included common terms like understanding relationships, interactions, and patterns, and interdependent and complex nature of the world (e.g., Strachan, 2012). In this thesis, systems thinking was defined as a valuable tool to achieve an integrative approach to understand relationships, interdependencies, complexity in the systems, seeing the big picture, seeing the multiple cause-effect relationships, considering long term solutions, personal worldviews and feeling part of the system (e.g.. Capra, 2005; Sleurs, 2008; Sterling, 2003; Tilbury & Cooke, 2005).

In the 21st century, in order to deal with complex, interrelated problems of the world and produce sustainable solutions, systems thinking is considered as an urgent need

(Capra & Luisi, 2014). Science teachers need to have STS to prepare future generations to cope with the current problems of the world and develop their abilities to create a sustainable future. ESD could provide a baseline for developing STS of science teachers. Therefore, in this thesis, pre-service science teachers' (PSTs) systems thinking skills (STS) were investigated through twelve STS which were determined in the context of SE and ESD. The important characteristic of these twelve skills is that they were identified in terms of combination of different frameworks in SE and ESD such as Assaraf and Orion (2005)'s systems thinking framework and UNECE (2011)'s ESD competencies framework. Further, these skills included both cognitive and affective components that are considered as essential for both SE and ESD. Thus, complex and multi-structured nature of systems thinking has been reflected through the twelve skills used in this thesis. Furthermore, the twelve STS that build up the framework of this thesis comprised of a wide range of skills (Table 1.1).

Table 1.1
Systems Thinking Skills in SE and ESD context

	Systems Thinking Skills
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

In this thesis, a series of data collection tools for measuring twelve STS were developed and an outdoor ESD course was designed to foster PSTs' STS in order to educate science teachers as ESD educators.

1.3 Measuring Systems Thinking Skills

Systems thinking arose as a critical skill in SE context (e.g., Assaraf & Orion, 2005; 2010; NRC, 2012) and as a key competency for ESD educators (e.g., Sleurs, 2008; UNECE, 2011). Since systems thinking is an emergent area in the education literature, there is still limited study for integrating systems thinking into education programs (Plate, 2010; Brandstadter, Harms, & Grobschedl, 2012). Moreover, there is not sufficient measurement tools to assess systems thinking skills therefore, researchers pointed out the need for developing various STS measurement tools (Boersma, Waarlo & Klaassen, 2011; Brandstadter et al., 2012). For this reason, it is necessary to conduct more research to measure and develop systems thinking skills (Brandstadter et al., 2012). In the literature, both qualitative and quantitative tools were suggested in order to measure STS. For instance, in the SE context, researchers conducted interviews, observations, concept maps and drawings (e.g., Assaraf & Orion, 2005; 2010a; 2010b). In the ESD context, in addition to interviews, written samples and case studies were the most preferred data collection tools (e.g., Connel et al., 2012; Lang, 2007; Sandri, 2013). Further, in order to evaluate STS level of the students and teachers some researchers developed a structured rubric (e.g., Connel et al., 2012; Hung, 2008; Remington-Doucette, Connell, Armstrong & Musgrove, 2013).

In this thesis, various instruments have been developed and used to obtain enriched data about systems thinking skills of PSTs. These tools included essay writing, case study analysis, interviews, field reports and concept maps. In the literature, written samples or case studies are suggested as the most feasible approaches to assess systems thinking skills (Wang & Wang, 2011; Zulauf, 2007). Systems thinking is a higher order thinking therefore, it could be evaluated through written samples (essay or case study) (Wang & Wang, 2011). Through case studies, for instance, real examples are provided to the students and they are asked to analyze these real cases. Thus, case studies are the effective tools to assess systems thinking skills (Remington, et al., 2013). Moreover, interviews are accepted as the major tools to measure STS (eg., Assaraf & Orion, 2005; 2010a; Batzri et al., 2015; Hmelo-Silver, Marathe & Liu, 2007). Interviews provide more detailed information about STS (Assaraf & Orion, 2005). In addition to interviews more recently, concept maps have been suggested as effective tools to evaluate STS (Brandstadter et al., 2012; Sommer & Lucken, 2010). However, in the literature there is not general consensus about which concept mapping practices are effective to evaluate STS (Brandstadter et al., 2012).

In this thesis, a combination of qualitative measurement tools in SE and ESD context has been carried out. Essay writing, case study analysis, field reports, interviews and concept maps have been used in order to validate PSTs' responses and thus, provide a detailed picture of STS developmental patterns.

1.4 Outdoor Education for Developing Systems Thinking Skills

In the literature outdoor education has been used for two main purposes: 1. to gain skills related to adventure activities such as rock climbing and 2. to educate individuals for a sustainable future (e.g., Beames et al., 2012; Hill, 2012). In this thesis, outdoor education has been utilized as a transformative approach for educating individuals about our planet and for building a sustainable future (Beames et al., 2012). Outdoor education holds a critical importance in ESD because it provides direct experience with the environment and develops physical, sensory, intellectual and affective ways of knowing and human relationship with the environment (Beames, et al., 2012). Outdoor education plays a vital role to develop our relationship with the planet to create a sustainable future (Beames, et al., 2012). Today, outdoor education is re-conceptualized as including social, economic and environmental issues of the 21st century (Hill, 2012). Further, the call is increasing as incorporating sustainability, socio-ecological and place responsive approaches into outdoor education practices (Higgins, 2009; Hill, 2012; Lugg, 2007 & O'connell, Potter, Curthoys, Dyment & Cuthbertson, 2005). Developing relationship with the environment is assumed as a precondition for understanding of sustainability. Outdoor education fosters individuals' connection with nature and helps them develop alternative worldviews for sustainable living and contribute to grow sustainability literate citizens (Lugg, 2007). In this way, outdoor education promotes a broad understanding and interaction that people need for building a sustainable future. Moreover, outdoor education is seen as an effective tool to develop systems thinking skills (e.g., Assaraf & Orion, 2005; Beames, Higgins & Nicol, 2012; Keynan, Assaraf, & Goldman, 2014). Outdoor education helps individuals understand complex natural systems (Assaraf & Orion, 2005). For instance, the relationship between plants and animals, cycling nature and human impact on natural systems could be better understood through outdoor education (Beames et al., 2012).

In parallel with the arguments in the previous studies (eg., Assaraf & Orion, 2005; Beames, Higgins & Nicol, 2012; Keynan, Assaraf, & Goldman, 2014) in this thesis outdoor education has been utilized as a tool for developing PSTs' systems thinking skills. Outdoor education provides a higher order learning by combining both cognitive and affective learning (Rickinson, et al., 2004). Therefore, in this thesis outdoor based ESD has been accepted as a holistic approach for developing PSTs' systems thinking skills.

1.5 Purpose of the Study and Research Questions

The purpose of this PhD thesis is to explore how science teachers could become ESD educators. More specifically, this thesis aimed to develop pre-service science teachers' systems thinking skills through an outdoor ESD course. The research questions leading the thesis are as follows:

1.5.1 Research Question 1:

What are the required competencies for science teachers to become ESD educators?

The first research question aims to investigate the required competencies for science teachers in order to become ESD educators. In this thesis, competency has been conceptualized as a complex, multi-structured concept including knowledge, intellectual and pedagogical skills, attitudes, willingness, and dispositions, which encompasses both cognitive and affective aspects (e.g., Sleurs, 2008; Strachan, 2012; UNECE, 2011). First, in order to investigate how science teachers could become ESD educators, required competencies for science teachers and ESD educators were compared based on the relevant literature (e.g., NSTA, 2012; UNECE, 2011).

Therefore, with this research question, the researcher aimed to reveal the gap between science teachers' and ESD educators' competencies and explore any key competencies for science teachers to become ESD educators. The investigation of this first research question guided the researcher to develop the following parts of this study.

1.5.2 Research Question 2 and Research Question 3

Research Question 2: How the key competency for science teachers to become ESD educators (systems thinking skills) can be measured?

In terms of gap analysis results systems thinking has become as a major competency to investigate. Systems thinking is a new area in education and it has been measured in specific contexts such as earth systems science, ecology, and sustainability and by means of specific measurement tools such as interviews, concept maps, written samples (e.g., Assaraf & Orion, 2005, 2010; Connel et al., 2012). To be able measure STS of the individuals, it is important to reveal what constitutes components of systems thinking in a specific context and how these components could be measured (Stave & Hopper, 2007). This thesis primarily identified twelve systems thinking skills in SE and ESD context for PSTs and developed various tools to measure these skills based on the context.

Research Question 3: What is the quality and validity of the developed systems thinking measurement tools?

Systems thinking has a complex nature; therefore, it is a challenging issue to evaluate affordances and constraints of the measurement tools designed to evaluate systems thinking skills (Assaraf & Orion, 2005). For this reason, there is a need to establish validity and reliability of the STS measurement tools. Since several instruments have been developed to measure STS in this thesis, a pilot study has been conducted to examine the validity and reliability of the tools.

1.5.3 Research Question 4:

What are the current level of systems thinking skills of pre-service science teachers?

This research question aimed to explore current level of STS of PSTs before the main study started. There are lack of studies related to exploring STS in teacher education, especially in science teacher education. Several researchers (e.g., Assaraf & Orion, 2005, 2010; Kali et. al., 2003; Evagorou, Korfiatis, Nicolaou & Constantinou, 2009) investigated STS of elementary school and high school students and these studies were conducted in different contexts. In addition to this, in Turkish context, there were not many studies conducted about exploring STS in science teacher education. For these reasons, this research question investigated current level of STS of PSTs.

1.5.4 Research Question 5 and Research Question 6

Research question 5: How can PSTs' systems thinking skills be developed through the outdoor based ESD course?

This research question aimed to investigate STS development process of PSTs in an outdoor based ESD course. Outdoor education develops individuals' connection with the place through understanding nature's integrity, it helps them understand the interactions between nature-society systems, and recognize how their behaviors influence the system (Hill & Brown, 2014). Additionally, outdoor education enables students to understand the components of a system and interrelationships among them; thus, it contributes to developing students' STS (Assaraf & Orion, 2005). In the 21st century, there is an increasing call for integrating sustainability issues, socio-ecological and place based approaches to outdoor education (e.g., Beames et al., 2012; Higgins, 2009; Hill, 2012; Lugg, 2007; Nicol, 2002). Therefore, the vision of outdoor education in this study embraces the call of the 21st century and it is based on the human-nature relationship, aspects of sustainability (social, economic and environmental), recognizing components and relationships in a system, and developing a sense of place. It was assumed that the outdoor based ESD course could be an effective way to develop STS of PSTs; and this research question helped the researcher to explore STS development process of PSTs' throughout the course.

Research Question 6: To What extent do PSTs reflect on their systems thinking skills to instructional planning in the light of the outdoor ESD course?

In the literature, several researchers (e.g., Brown & Champione, 1994; Senge, Cambron, Lucas, Smith, Dutton & Kleiner, 2000) argue that children are born as natural systems thinkers that they could recognize interdependencies in the world before they go to school. However, school programs fragment knowledge into unrelated parts and do not provide many opportunities for students to see the patterns, relationships in a system, and suppress students' natural thinking in systems (Sweeney & Sterman, 2007). Unfortunately, our culture continues to adapt materialistic worldviews although natural systems work in a complex and non-linear way (Capra, 2005). Systems thinking holds a critical importance for understanding complex, cycling natural systems and interdependencies among sustainability issues.

Teachers play an important role to prepare their students as responsible citizens for a sustainable future (Washington State OSPI, 2008); therefore, pre-service teacher education is very important to achieve a social transformation in the world (Foley, Archambault, & Warren, 2015). Pre-service science teachers could provide learning environments to their future students to unearth their natural systems thinking skills. They could educate them as systems thinkers who could realize interconnectedness in the world and feel responsible for creating a sustainable future. Therefore, this research question focused on what extent PSTs could reflect STS in their instructional planning (lesson plans) under the light of outdoor ESD course.

1.6 Significance of the Study

With regard to rapid developments in science and society, SE has been evolved through the years (Deboer, 2000). The complexity and interrelatedness of the global problems in the 21st century constituted the need for integrating ESD into the education system and accordingly, integrating sustainability to SE has come to the agenda of the researchers (e.g., Carter, 2008; Burmeister & Eilks, 2012; Gough, 2008; Hestness, McGinnis & Breslyn, 2015; Tippins, Pate, Britton & Ammons, 2015). Researchers and education philosophers assert that students and teachers should be prepared for designing a sustainable society. For instance, according to Orr (1992), teachers should develop both scientific literacy of students and also prepare them to make decisions for sustainability and know the ways of living in a harmony with their environment. Similarly, Stratton et al. (2015) argue that science teachers should educate children and other citizens about sustainability. Recently, during the International Scientific Conference, UNESCO (2015) emphasized the need for a holistic approach to SE in order to cope with global challenges such as climate change. In addition to recent developments related to SE around the world, in Turkey sustainable development concept has been integrated to new SE curriculum and it aims to grow scientifically literate individuals who are aware of sustainability and also to help young learners realize the relationship between human, environment and society (MoNE, 2013).

There are increasingly more efforts in order to make collaboration between SE and ESD around the world and there is a strong need for this collaboration as education plays an important role in constructing a sustainable future. Therefore, this thesis holds a critical importance to contribute to the literature at the national and international level in terms of both theoretical and practical aspects.

The fundamental significance of this thesis is, therefore, due to its bringing four of the key components of the 21st century education (e.g., Carter, 2008; Hill, 2012) (systems thinking, SE, ESD and outdoor education) together and employing an empirical study combining these components. Hence, bringing the key components together, this thesis is aiming to contribute to the literature by measuring and developing systems thinking skills of PSTs to become ESD educators.

The second significance of this thesis comes from the presentation of twelve STS in SE and ESD context. The skills were determined and defined by an intense literature review and through expert opinions, and it included both affective (e.g., empathy) and cognitive components (e.g., identifying components in a system) and thus reflected multifaceted nature of SE and ESD.

At the national level, this thesis is the first to define systems thinking skills in two contexts (SE and ESD), and therefore, it promises to shed a light for SE researchers and program developers to integrate ESD and systems thinking concepts to the programs.

From a practical perspective, another significance of this thesis is to produce reliable and valid tools for assessing STS in the education literature (Brandstadter et al., 2012). Researchers generally developed specific tools for measuring systems thinking in specific contexts (e.g., Assaraf & Orion, 2005; 2010). In this thesis, a series of data collection tools were developed or adapted to measure STS of PSTs, and they were pilot tested for constructing validity and reliability issues. Therefore, this thesis might fill in the gap offering some tools to measure STS in SE and ESD context.

Another practical significance is that an outdoor ESD course was designed for developing STS of PSTs. The researcher claimed that the outdoor based ESD has a potential to foster STS of the PSTs. Outdoor education has been found to help individuals understand components and interactions of the complex systems through directly experiencing the natural phenomena (Assaraf & Orion, 2010;

Beames et al., 2012). Outdoor education in Turkey is mostly pursued by several environmental non-governmental organizations (NGO) and it is not completely integrated to school curriculum. Therefore, this thesis could open a new window and a new perspective for SE and ESD researchers in Turkey to take into account the potential of outdoor education for creating a multidisciplinary environment and developing students' and teachers' systems thinking skills. Further, the results of this thesis will provide information about the current state of PSTs' systems thinking skills and inspire both SE and ESD researchers in terms of using these results by designing their studies.

In conclusion, this thesis aims to have unique contributions to both SE and ESD literature in terms of suggesting a model to educate science teachers as ESD educators in order to meet the demands of the 21st century (Figure 1.1).

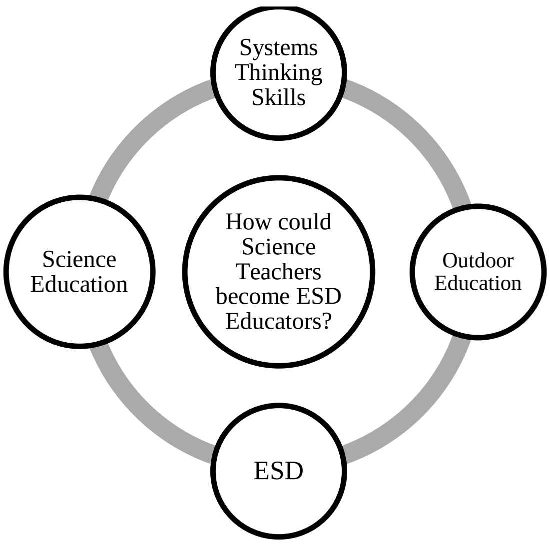

Figure 1.1. Key Components of the Thesis

CHAPTER 2

LITERATURE REVIEW

2.1 The Evolution of Science Education

The purpose of science education (SE) is to grow scientifically-literate individuals with an understanding of science content, skills for drawing conclusions from scientific issues and evaluating scientific cases (Wang & Schmidt, 2001). SE has been evolved for 100 years. During the early years of 20th century, SE was influenced by the education philosophers like John Dewey. Because of the influence of Dewey's education perspective, it was accepted that SE and education in general were related to contemporary life (Deboer, 2000). The role assigned to SE was to raise individuals who have ability to take part in social life. More specifically, the major target of SE was to integrate scientific knowledge into real life activities. From 1960s to 1980s, SE became more and more interested in the strategic role of scientific knowledge in society. In 1960s, through industrialization, rapid developments of technology and with the launching of Sputnik I, the context of SE began to change (Chui & Duit, 2011). Furthermore, national security concerns in the World War-II and developments in technology brought a new approach to science education which was called scientific literacy. Deboer (2000) noted that scientific literacy has evolved as a general concept since 1980s, and it has been defined by several scientific boards (National Research Council (NRC), 1996; OECD, 2004)

For instance, the Organization for Economic Cooperation and Development (OECD, 2004) defined scientific literacy as ‘‘the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity'' (p. 40). Yet, the focus of SE continued to evolve in line with the developments in science and technology and people's interests (Deboer, 2000). SE has been influenced by industrial and economic developments as well as digital technologies. Therefore, the aim of SE is described as to raise scientifically and technologically informed citizens (UNESCO, 2008).

In these years, Carter (2008) emphasized that SE needs to develop new perspectives to promote sustainability. Furthermore, Choi et al. (2011) note that developments in technology and engineering have brought ethical, moral and global concerns such as global warming, energy crisis, air and water pollution, and these developments have also had impact on the changing focus of SE. Choi et al. (2011) emphasize that there is a need to reconsider the meaning of scientific literacy based on the demands of the 21^{st} century society. The authors suggested that definition of scientific literacy needs to be revised so that it includes global perspectives, understandings and capabilities to build and maintain a sustainable world.

Indeed, Meadows, Meadows, Randers and Behrens (1972) who are the authors of the report of Limits to growth claimed that the resources of the Earth is finite and if humans maintain unlimited growth in industrialization, population, food production and resource depletion, eventually, the civilization will collapse. In the report, the authors pointed out that technology-centered solutions don't have impact on the problems of depletion of resources, pollution etc. They implied that every new technology has side effects. They also mentioned that green revolution is a good example of indicating social-side effects of the new technologies. New seed varieties, fertilizers, pesticide productions were presented as a new agriculture technology, yet they brought some social problems on traditional cultures (Meadows, et al. 1972). Today, family farms are lost and big companies have been managing food production in the world. In addition to a number of SE researchers, Meadows et al. (1972) put forward that technological solutions have social and psychological side effects, and they caused new problems in the world.

As understood from the above discussions, only technology and engineering centered SE does not provide solutions for sustainability problems today. There is a need to strengthen the relationship between SE and social studies by addressing sustainability. As Maxwell (2009) noted that science could initiate a global degradation in the world, yet, it could also be a solution for sustainability. The important point is related to how to interpret and use science.

Maxwell (2009) suggests that the reductionist view of science contributes to unsustainability today. Actually, only considering technology-focused science without thinking social, cultural and political aspects shows reductionist view of science. Reductionist thinking in science has a long history, reaching back to Newtonian-Cartesian worldview (Maxwell, 2009). This worldview appearing in the 16^{th} and 17^{th} century assumed that world worked through mechanical rules (Capra, 1982). This view suggested that natural systems could be understood by fragmenting them into small parts (Capra, 1982). As discussed by Maxwell (2009) and Orr (1992), however, such thinking has adverse effects on natural systems and cause unsustainability in the world.

How we view science also influences our interpretation of SE. Today, most of the science textbooks ignore big ideas, important concepts and lead students to memorize a set of facts; thus, they fail to encourage students to develop a systematic and integrated way of understanding of science (Liu & Hymelo-Silver, 2009). For instance, students and student teachers' drawings of a scientist as a lab-coated male, bald, using test tubes etc. demonstrate that science is understood as abstract, physical, unemotional and in a reductionist view (Littledyke, 2008). Students learn science in a fragmented way in schools, and science teachers continue teaching in this way as they were taught at schools and at the universities (Tytler, 2007). Therefore, the shift in the perception of science influences the view of SE as well.

The evolution of physics from Newtonian-Cartesian to modern physics brought a fundamental shift from reductionist thinking towards systems thinking, requiring the need to reconsider science and SE (Maxwell, 2009). More recently, systems thinking has drawn the attention of science educators. Systems thinking has been defined as one of the important 21st century skills (e.g., Choi et al., 2011). For instance, NRC (2010) determined the definitions of the 21st century skills for SE. These skills included adaptability, complex/communication/social skills, non-routine problem solving skills, self-management and self-development, and also systems thinking. In this report, systems thinking was described in line with the job performance standards such as understanding the relationship between work responsibility and company's strategy, values and goals. Systems thinking was defined according to needs of workplaces and economists in the report of National Research Council of the National Academies.

Nevertheless, several authors (e.g., Capra, 2005; Choi, et al., 2011; Orr, 1992; Sterling, 2003) explain holistic view of science or systems thinking as a solution towards the current problems of the world. For example, Choi, et al. (2011) criticizes the definition of scientific literacy that is providing a partial and fragmented picture of the system and not developing understandings and abilities of individuals to build a sustainable planet for all people. The authors emphasize that science should ask these questions like:

> What are the likely effects that inventing, manufacturing and using nanoscience products will have on the health of my family and my community?" or "What might be long range effects of nanoscale waste on the environment both locally and globally?". (p.671).

Therefore, Choi et al. (2011) re-conceptualized scientific literacy and suggested five dimensions of scientific literacy which are "21st century content knowledge" (dealing with the issues of climate change, consequences of genetic engineering, destruction of the environment and lack of energy, "Habits of mind" (related to key elements of communication and collaboration skills, systems thinking, the use of

arguments to support claims, build arguments and information management skills, "Character and values" (related to a value system for the 21st century; ecological worldview, socio-scientific accountability and social and moral compassion, "Science as a human endeavor" (related to a contemporary understanding of the nature of science (NOS) and "Metacognition and Self-direction" (related to self-directed planning, self-directed monitoring and self-directed evaluating). The authors point out that these five dimensions are not separated, and they are all related to each other, and working on these five dimensions is a new focus for scientific literacy and SE. It is revealed that systems thinking has proposed as a new way of understanding of science and as a component of scientific literacy as well.
Moreover, in accordance with the discussions of integrating sustainability into SE, more recently, NRC (2012) has developed a new framework for K-12 science education with the aim of developing, especially, science and engineering knowledge of students and supporting careers in science, technology and engineering. NRC (2012) included dimensions related to scientific and engineering practices, cross-cutting concepts that combine science and engineering and core ideas in the fields of physical sciences, life sciences, Earth and space sciences and engineering and technology and applications of science. This new framework brought different perspective together in SE although it has been criticized of having limited view of sustainability, not including environmental, social, ethical and political components (e.g., Feinstetin & Kirchgasler, 2014)

Briefly, science has proceeded a paradigm shift from mechanistic view of science towards holistic, systemic view of science, which means a change from seeing the world as a machine to understanding the world as including networks and relationships (Capra, 2002). The changes in philosophy of science, scientific revolutions, developments in science and technology influenced SE as well. Traditional ideas in science that suggest scientific and technological solutions are the best way to deal with global environmental problems are still acceptable. However, there is a need to reconsider the aim of SE, its implications and consequences (Colucci-Gray et al., 2013). Today, SE could give more importance to relationships, aspects of life, cultural and ecological sustainability since SE could make a contribution to the important dilemmas of the 21st century (Carter, 2008). Therefore, SE could be re-conceptualized through addressing the needs of the 21st century citizens. That is, in the 21st century, people need to have an understanding of big ideas, holistic perspective, systems thinking skills (STS), and they should be aware of their responsibilities while making choices and decisions for sustainability (Carter, 2008; Choi et al., 2011).

How could we prepare today's citizens for the needs of the 21st century? As an answer to this question, ESD type SE for integrating sustainability and systems thinking perspective is suggested as an approach since ESD provides an interdisciplinary approach that helps individuals understand interconnectedness in the natural, built, economic and political world (Feldman & Nation, 2015). Figure 2.1 displays the evolution of SE from past to present.

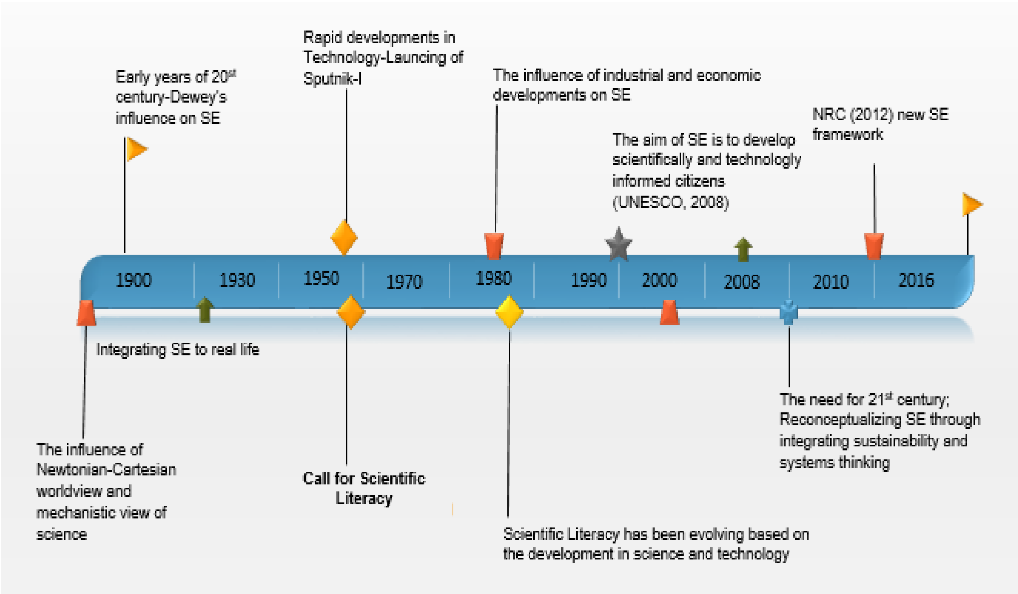

Figure 2.1 The evolution of science education

2.2 The Need for ESD

Because of the changing perspectives and paradigm shifts in science, today SE has more focused on environmental issues (McFarlane, 2012). Several authors point out that SE should not only focus on understanding the Earth system but also should work for an equitable, just and sustainable world (e.g.,Gough, 2007; Carter, 2008). From the past to present, humans have always tried to change and shape the Earth (Carter, 2008). As we know that over the last two centuries, human activities have been influencing the environment and in the last half of the century, natural resources have been declining seriously (Palmer, 1998). Socio-economic factors accelerate environmental crisis and unsustainable practices (Vare, 2014), and level of inequality is increasing among the counties (OECD, 2008). Actually, current problems in the world are called as wicked problems having multiple reasons and cannot be solved with generic principles or linear thinking (Blackman, Elliot, Greene, Harrington, Hunter, Marks, Mckee & Williams, 2006). Wicked problems are related to complex social problems such as health issues and global warming (Blackman et al., 2006). In order to solve these kinds of problems, individuals should be equipped with necessary skills and competencies that could be possible through a transformation towards ESD (Wiek, Xiong, Brundiers & Van der Leeuw, 2014). In order to understand where and how this transformation started, examining major historical documents is required. First, EE as a concept was introduced through two documents which are IUCN (1970) and Tbilisi (UNESCO-UNEP, 1977). The aim of EE defined in these documents was to develop pro-environmental behaviors and encourage active citizenship (Vare, 2014). Actually, the roots of EE dates back to three past educational movements which were outdoor education, nature study and conservation education (Disinger, 2001). Before the environmental movements in 1960, environmental studies were limited to observation of the natural world. Although EE has a broader and comprehensive meaning, it has not been successful to contribute to educational policy and practices (Vare, 2014). Therefore, similar to EE building on its antecedents (nature study, conservation study etc.), ESD has built on EE in the same way (Marcinkowski, 2010).

The seeds of ESD were planted in 1970s in line with the conferences including the man and environment conference in Stockholm (UN, 1972) and the UNESCO-UNEP conference on EE in Tbilisi in 1977 (Wals & Kieft, 2010). ESD first emerged in the United Nations Conference on Environment and Development (UNCED), Earth Summit in Rio de Janerio in 1992. Chapter 36 of Agenda 21 exracted from UNCED (1992) determined four goals:

- “Promoting and improving quality of education”
- “Reorienting existing curricula”
- “Increasing public awareness of sustainable development”
- “Developing training for all sectors” (p.32)

Wals (2007) emphasized that these major historical documents reflected the changes which are shifting from environmental problems to sustainability problems and changes from EE to ESD.

Thus, DESD that started in 2005 aimed to develop and reorient education systems towards sustainability in ten years. At first glance, this aim was considered for formal curriculum and revising curriculum for sustainability. However, at the end of the DESD, a richer understanding for ESD applying all sectors and interests was developed (UNESCO, 2014). In the early years of ESD, it focused on the meaning and content of sustainability. Yet, in the recent documents, its education aspect has gained more importance. In general, there has been a shift from training and instruction towards learning and capacity building for ESD (Wals & Kieft, 2010).

A current vision for ESD is "what constitutes a good quality education", which refers to "what people learn, its relevance to today's world and global challenges and how people develop skills and attitudes respond to these challenges now and for future generations" (UNESCO, 2014, p.21). Not only formal education, but also non-formal (e.g., nature centers, non-governmental organizations) and informal education (e.g., television, radio) have a responsibility for implementing ESD (Mckeown, 2002). ESD pedagogies are developed at all levels of education (formal, non-formal, informal) (UNESCO, 2014). ESD pedagogies hold a potential to create a transformation from memorization to participatory learning (UNESCO, 2012) and moving from the classroom to the community environment (UNESCO, 2014). In addition to the inclusion of ESD in school curriculum, it is critical to reveal how to apply ESD in classroom teaching. ESD requires a shift from traditional teacher-centered pedagogies towards collaborative, discovery and problem-solving approaches (UNESCO, 2014). In the final reports of DESD (UNESCO, 2014), it is reported that one of the important challenges for the future is teacher preparation for ESD. Therefore, UNESCO declared that teacher education needs a high priority (UNESCO, 2013). There are around 70 million teachers in the world, and they hold a great potential to shape individuals' worldviews, attitudes, abilities to create a sustainable world (Mckeown, 2012). According to final report of DESD (UNESCO, 2014) ESD in teacher education has shown an increase from emerging interest level in 2005 to significant progress level in 2013. Some countries have already created their own environment and sustainability education standards and determined teacher education requirements for sustainability. For instance, Washington State reported that all teachers need to prepare students as responsible citizens for a sustainable world. (Washington State OSPI, 2008, p.7). In the report, teacher requirements are determined in three components which are content, methodology and competences. For example, some of the teacher competencies are that teachers should feel connected to an environmental and sustainability education community, and they should be able to make contributions to this community. Scotland is another country, for instance, that determined professional standards for teacher education which include two specific principles. Those principles are that teachers should be knowledgeable about sustainability and competent to apply ESD (Higgins & Kirk, 2006).

Moreover, in the final report of DESD, it was suggested that ESD competencies, professional standards and certifications for teachers should be explored by the governments and teacher education institutions (UNESCO, 2014). Therefore, some institutions have already determined required teacher competencies for ESD (e.g., United Nations Economic Commission for Europe (UNECE), 2011; Sleurs, 2008). The expert group at UNECE aimed to develop educators' knowledge, skills, attitudes, understandings and values for ESD (UNECE, 2011). As ESD could take place in all education levels (formal, non-formal and informal), they developed ESD competencies not only for teachers but also for all educators. It was suggested that initial teacher education institutions should consider these competencies and find the best suitable areas in their programs in order to integrate ESD competencies (UNECE, 2011). These competencies determined by UNECE (2011, p.12) included three essential characteristics of ESD: "a holistic approach" (related to integrative or systems thinking and practice), "envisioning change" (related to learning from the past, present and exploring alternative futures) and "achieving transformation" (related to transforming the way people learn). Furthermore, a teacher education department in Belgium initiated a European Commission-funded project to develop a framework to integrate ESD into teacher education. As a result of this project, teachers' competencies for ESD were determined (Sleurs, 2008). In this model, teacher is defined as an individual in a dynamic relationship with their students, their colleagues and the wider society rather than as an instructor. In the report, five competency domains including cognitive and affective dimensions were identified (Sleurs, 2008). These five competencies are knowledge, systems thinking, ethics, values, emotions and action. In this model, it is noted that these competencies are not separated from each other, but they are all related. For instance, systems thinking is linked to emotions since it refers to understanding others' perspectives, beliefs; thus, it helps build empathy with other people (Sleurs, 2008).

Wiek et al. (2011) conducted a review of key competencies for sustainability in higher education. The authors examined relevant literature of key competencies, made a synthesis of the literature and determined critical gaps in conceptualizing of competencies for sustainability. They revealed five core competencies in higher education which are "systems thinking competence", "anticipatory competence", "normative competence", "strategic competence" and "interpersonal competence" (Wiek et al., 2011, p. 205). They concluded that there is a growing interest for determining key competencies in sustainability. Yet, there is a need for improving these competencies and conducting empirical, follow-up studies related to these sustainability competencies in higher education (Wiek et.al, 2011). In Wiek et al. (2011)'s study, they did not specifically emphasize ESD competencies for teachers; instead, they focused on general competencies in higher education. Nevertheless, there are similarities among these competencies recognized by UNECE (2011) and Sleurs (2008). The common critic found among these competencies is that ESD educators should have a holistic approach, systems thinking or integrative thinking. For instance, Wiek et al. (2011) noted that sustainability requires a comprehensive, systemic understanding; therefore, STS are crucially important for sustainability education. Furthermore, UNECE (2011) reported that systems thinking is a valuable tool for ESD as it reflects interrelationships between the human and natural environment and among different cultures in the world. Moreover, Sterling (2004) mentioned insights from systems thinking. He developed an integrative view of education and a change of paradigm across education, and he used the term of "sustainable education". Sustainable education refers to a systems view of sustainability (Sterling, 2004). That is, all systems include subsystems and sustainability is related to sustaining of a system related to its environment (Sterling, 2004). Sterling (2004) notes that the health of a system depends on the health of its subsystems. The author emphasizes that a transformation and a paradigm change is necessary in education; hence, systems thinking which explores relationships is essential and helpful. Briefly, Sterling (2009, p.1) notes that "If we want the chance of a sustainable future, we need to think relationally."

For this reason, systems thinking is proposed as one of the important ESD competencies for teachers and educators. Sleurs (2008) noted that systems thinking is related to awareness of being part of the global system and relationships among economy, ecology and society. Therefore, systems thinking is at the center of ESD (Sleurs, 2008). How ESD has evolved around the world is summarized in Figure 2.2.

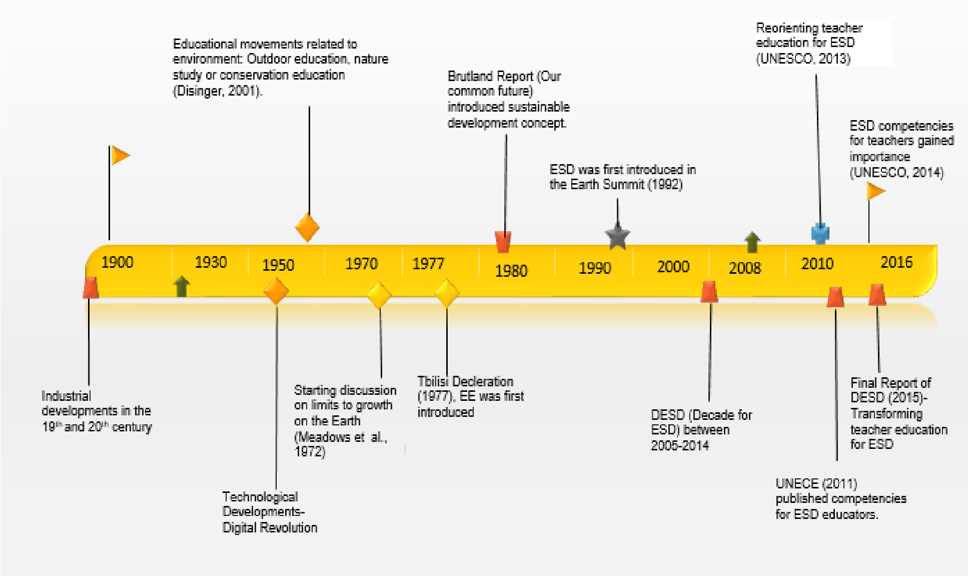

Figure 2.2 The evolution of ESD

2.3 The Situation of SE and ESD in Turkey

ESD provides a vision for people to understand the world and how to cope with the global problems that threaten our future (UNESCO, 2011). As presented in Figure 2.2, in the recent years, the issue of competencies for ESD educators, and especially, systems thinking and integrative approaches has been more emphasized.

In the 21st century, SE should hold a wider perspective to prepare citizens who could explore components of sustainability (social, environmental and economic) and who could make social, political, environmental decisions for themselves and for the community (Choi et al., 2011; Feldman & Nation, 2015). Therefore, there is a need to strengthen the relationship between ESD and SE. As mentioned earlier, current view of science and SE contributes to a fragmentary and reductionist way of thinking (Littledyke, 2010; Maxwell, 2009). Therefore, similar to ESD, systems thinking poses importance in SE. In order to understand what is behind our actions and recognize the big picture in the system, there is a need to develop STS of the individuals (Choi et al., 2011). Within ESD, we could provide this integrated way of understanding or systems thinking through a more comprehensive, multi-dimensional and holistic approach (Burmeister & Eilks, 2012). For this reason, it is critical to prepare science teachers according to new vision of SE which is related to sustainability and systems thinking perspective. Carney (2011) suggested that future science teachers' sustainability literacy should be developed as well. That is, they should have a global perspective, an understanding how people and places are interconnected, a perspective related to how complex systems work, respects for the limits and systems thinking and interdependence (Church & Skelton, 2010; Nolet, 2009). Therefore, it is not enough to integrate sustainability into SE programs, we need to develop competencies (including systems thinking) of future science teachers for ESD.

Science courses were integrated into the Turkish curriculum after Turkish Republic was founded in 1923. In 1924, all educational institutions began to be managed by Turkish Ministry of National Education (MoNE) (Gozutok, 2003). In those years, when the first village schools were opened in 1927 and the aim of these schools was to educate villagers; therefore, the program included more agriculture courses than science courses. After John Dewey visited to Turkey, a new SE curriculum was developed and the new curriculum included more pragmatist ideas. After the Second World War, like other countries, Turkey followed modern science curriculum developments in USA in 1960s (Sözbilir, Kutu & Yaşar, 2012).

Rapid developments in science and technology in Turkish society influenced curriculum development studies through the years (Gozutok, 2003). Based on the need of the 21st century, MoNE initiated SE reform. For this aim, the first attempt was to change the name of science education to science and technology education considering the aim of the curriculum in 2004 (MoNE, 2004). The science and technology education program initiated in 2004 has been influenced by the paradigm shifts in science around the world and incorporated the constructivist approach. The aim of the program was to raise scientifically and technologically literate individuals and develop students' critical thinking, creativity, problem solving skills and participation on decision making process (MoNE, 2004). More recently, SE program was changed again by MoNE in 2013. The purpose of new elementary science education curriculum is to bring up scientifically literate individuals. Yet, this new curriculum emphasized the relationship among science, technology, environment and society more. The curriculum aimed to develop students' understandings of how science influences technology and society and how society influences science and technology. Furthermore, new curriculum aimed to help students recognize the interconnections among science, technology and society and to develop sustainability awareness of the students. Sustainablity in the new curriculum has been defined as using natural resources by considering the needs of the future generations and as informing students about the social, economic and individual benefits of the less consumption (MoNE, 2013). The new curriculum also emphasized that students should be aware of the positive and negative impacts of the technological developments.

It is understood that new curriculum does not only promote technology-centered idea but also it encourages students to understand the relationship among science, technology, society and environment. Moreover, it was the first time we could see the concept of sustainability in the new curriculum. In this context, it is understood that paradigm shifts in science and SE has impacts on Turkish SE curriculum. Especially, 2013 curriculum reflected new ideas, new perspectives and new approaches in SE.

Turkey has followed developments in SE in the world through the years, and recently, new curriculum has reflected new ideas, new perceptions related to SE like integrating sustainability concept to SE programs.

Actually, in Turkey, there is not an educational policy for ESD; yet, several national programs emphasized the need for ESD in education programs. For instance, UNESCO-Turkey (2011) carried out several studies with its global principle "education is for all". In terms of ESD, a committee has been established and studies about ESD are conducted with MoNE, Elementary General Management and Ministry of Environment and Forestry. Being the focal point for ESD, UNESCO-Turkey (2011) announced the main goals for implementing ESD in Turkey as follows:

- To strengthen the connections of knowledge, sharing and experience among people
- To increase the quality of education in terms of ESD.
- To help Turkey develop an ESD policy

In order to meet the goals mentioned above, an Eco-School project has been launched by Turkish Environment and Education Foundation (TÜRÇEV) to increase students' and teachers' environmental awareness, their environmental knowledge and active citizenship**.** In recent years, however, National Reports related with international conventions, (e.g. National Capacity Action Plan, 2011; Turkey's Sustainable Development Report, 2012 and National CC Strategy, 2010) address the necessity of reevaluation of Turkish education system in terms of Rio principles. In Turkey's Sustainable Development Report prepared by Ministry of Development (2012), it is proposed that courses should be prepared and integrated into the curriculum to develop students' sustainable production and consumption understandings and to increase their environmental awareness. It is also emphasized that educational institutions should be in cooperation with non-governmental organizations and media. In parallel with these arguments, recent SE curriculum has included sustainability concept.

In research based context, there are a variety of studies investigating PSTs' opinions, beliefs, attitudes, motivation and insights related to the environment and sustainability (e.g., Karaarslan, Ertepınar & Sungur, 2013; Kılınç & Aydın, 2011; Tuncer, Tekkaya & Sungur 2006; Tuncer, Tekkaya, Sungur, Çakıroğlu, Ertepınar & Kaplowitz, 2009). Yet, there is lack of debate surrounding the relationships between SE and ESD or integration of sustainability issues into SE.

Furthermore, sustainability is not a major concern of the lecturers in faculties of education including science teacher education as explored in the study of Cavaş, Ertepınar and Teksöz (2014). The authors investigated opinions of the lectures in faculties of education about the integration of sustainability into their lectures. They found that lectures in faculties of education rarely integrate sustainability concepts into their lecture contents. Besides, the authors emphasized that lecturers refer only to one aspect of sustainability (usually environment); therefore, they do not have a holistic way of understanding sustainability. Similarly, there is a lack of courses integrating sustainability into SE in the science teacher education programs.

While discussions are going on for integrating sustainability into SE programs, more recently, SE in Turkey has been influenced by the new SE framework developed by NRC (2012) in USA. Several researchers (e.g., Çorlu, 2014; Çorlu, Caprara, Çorlu, 2015) emphasized that STEM education is critically important for the economic competitiveness of Turkey. Çorlu et al. (2014) notes that Turkey needs to have integrated teacher education programs including STEM education in order to meet the needs of knowledge-based society. Research interest in STEM education has been increasing in Turkey in the recent years.

Briefly, Turkey has been influenced by the reforms related to SE throughout the history of SE. In the recent years, there are attempts to create SE programs by addressing the relationship among science, technology, society and sustainability, and thus, creating an integrated way of understanding.

2.4 Competencies of Science Teachers

In accordance with the arguments about the role of SE in the 21^{st} century, discussions are also going on about what could be the role of science teachers in the future. Many authors, educators and researchers have been working on the new standards for future science teachers. They have especially focused on competencies of science teachers (Naumescu, 2008).

Actually, competencies of science teachers have been discussed for more than 50 years, and generally two categories for competencies were suggested: One of the categories is related to what could be the main skills to be a good science teacher, and the second one refers to the necessity of SE for today's young people (Naumescu, 2008). The first category, the main skills for being good STs, was emphasized by Barnett and Hodson (2001). The authors addressed that good science teachers should have practical knowledge, pedagogical content knowledge, professional knowledge and classroom knowledge. Moreover, Osborne and Millar (2000) discussed the necessity of SE for young people today, and they criticized that young people are not so familiar with scientific ideas.

Therefore, they suggested several competencies for science teachers as follows:

1. Science teachers should be familiar to scientific ideas.
2. Science teachers should increase students' sense of curiosity.
3. Science teachers should develop students' scientific skills.
4. Science teachers should prepare the most appropriate assessment tools.
5. Science teachers should make relationship between science and technology.
6. Science teachers should be open to new techniques and innovations.

In general, SE literature focused on three components related to teachers' competencies which are subject matter knowledge (SMK), pedagogical knowledge (PK) and pedagogical content knowledge.

For instance, after constructivist learning theories came into agenda of SE, what could be competencies of constructivist science teachers have been discussed. Nezvalova (2007) reported constructivist science teachers' competencies in eight dimensions as follows:

1. Understanding science content (scientific concepts, theories).
2. Understanding nature of science.
3. Understanding inquiry based research.

4. Having general skills for science teaching.
5. Implementing effective and coherent curriculum.
6. Using multiple assessment techniques.
7. Safety and welfare (providing safe environment and respecting for all living things).
8. Professional development.

These competencies reported by (Nezvalova, 2007) especially focused on the main competencies to be a good science teacher.

Furthermore, standards for SE have been provided in the USA, and they described a comprehensive, clear and consistent science content, essential components of SE, teaching practices and assessment (Bybee, 2014). To illustrate, National Science Teacher Association (NSTA, 2012) determined pre-service science teachers' standards. Similar to Nezvalova (2007)'s competencies report, NSTA (2012) reported the main competencies to be an effective science teacher. These standards included components like content knowledge of science, content pedagogy, providing learning environment that is appropriate for science learning, providing safety and welfare, revealing the impact on student learning (demonstrating that scientific knowledge is gained correctly) and also professional development and skills. As Kauertz, Neumann and Haertig (2012) criticized that teacher competencies mostly consist of cognitive aspects. The competencies revealed from the above mentioned reports also included cognitive aspects rather than affective aspects. So far, the report of Nezvalova (2007) and NSTA (2012) have not incorporated any competencies related to ESD and also systems thinking as one of the ESD competencies. Furthermore, as mentioned in the previous sections, NRC (2012) developed a new framework for SE. This framework included new visions for SE, which mainly focused on science and engineering practices, cross-cutting concepts that connect the study of science and engineering and core ideas in four disciplines (physical sciences, life sciences, Earth and space science, engineering, technology and applications of science). This new framework also implied changes in science teacher education. It is implied that there should be a reform in science teacher education based on this new framework. It is suggested that teachers should integrate science and engineering practices, and they should develop an integrated approach to curriculum, instruction and assessment (Bybee, 2014).

In addition to above mentioned basic competencies for science teachers which are related to subject matter knowledge, pedagogical methods, implementing curriculum and assessment, Bybee (2014) suggested personal qualities as an essential competency for science teachers. The author emphasized personal qualities as personal relations with students and willingness to teach science. In addition to cognitive aspects, he emphasized that science teachers should have several affective competencies as well.

In accordance with the reforms in SE which focus on technology and engineering practices, it is strongly suggested that pre-service science teachers' requirements and competencies should be prepared based on the reforms in SE. Systems thinking has been only described in engineering context instead of expressing systems thinking as a competency that is critical in SE and ESD.

In Turkey, context MoNE introduced a report about competencies of teachers in 2008, and science teachers' competencies were presented in the same year. In the report, Turkish science teachers' required competencies were determined in the five main themes which are planning and organizing of learning and teaching process, scientific, technological and social development, monitoring and evaluating development of students, the cooperation between school, society and family and professional development.

In particular, MoNE (2008) introduced basic competencies for Turkish science teachers, and these competencies have lack of ESD competencies including systems thinking.

In the literature, there is a lack of empirical studies related to competencies of science teachers. A few studies focused on designing a sustainability education course for teachers in order to develop sustainability literacy (including systems thinking) of pre-service teachers, For instance, Foley et al. (2015) designed a sustainability science course for pre-service teachers. They built the course on the new SE framework developed by (NRC, 2012), and they broadened the perspective of the course, and they aimed to develop pre-service teachers' sustainability literacy through the course. Furthermore, they developed a sustainability education framework for this course. This framework included four sustainability competencies which are futures thinking, values thinking, systems thinking and strategic thinking. Through the course the authors assessed pre-service teachers' sustainability understanding and they concluded that pre-service teachers were able to understand the complex, multifaceted nature of sustainability after the course better.

In the literature, it is addressed that SE should be in cooperation with ESD, and it should encourage individuals to develop their STS. Required competencies for science teachers lack of sustainability and systems thinking perspectives. Therefore, there is a need to develop pre-service science teachers' systems thinking which has been accepted as a critical skill for ESD and SE.

2.5 The Critical Skill for ESD and SE: Systems Thinking

Systems thinking is seen as a critical skill for ESD since ESD holds an integrated and holistic approach. In SE context, from the past decades to today, paradigm shifts occurred in science from mechanistic view of life towards holistic view of life or from seeing the world as a machine to seeing the world as a living system including networks, relationships (Capra, 2002). This paradigm shifts influenced SE as well. Several reforms occurred in SE and systems thinking came into agenda of SE researchers. This part of the literature review focused on systems thinking approaches, systems thinking measurement tools both in SE and ESD context and implementation of ESD for developing systems thinking skills.

2.5.1 Systems Thinking in Education

Systems thinking was revealed as a reaction to reductionist or linear thinking which assumed that a whole system could be understood through analysis of its parts (Remington-Doucette et al., 2013). Senge (2006) defined systems thinking as a discipline for understanding the whole system, as a framework for recognizing the relationships in the system and as a set of principles and techniques to see the interrelationships. Furthermore, several philosophers and researchers (e.g., Capra, 1996; Sterling, 2003; Tilbury & Cooke, 2005) expressed systems thinking as a framework that is related to seeing the big picture, understanding complex systems and relationships.

Hogan and Weathers (2003) pointed out that students should be educated as systems thinkers in order to be effective problem solvers and decision makers in this century. They defined systems thinker as an individual who could understand the complex systems, see the multiple cause and effect relationships in the system, see possible side effects of the problems and consider long term consequences. Moreover, in their analysis, they identified two components of systems thinking in ecology context. One is related to cognitive components of systems thinking in ecology. These cognitive components included items such as basic knowledge related to system, perception about the systems, motivation for understanding systems and collaboration skills. Secondly, they described contextual components of systems thinking in ecology. Contextual components, on the other hand, included items like interactions between social and cultural contexts, personal relations etc. Thus, the authors created an expanded definition of systems thinking in ecology field.

Kali, Orion and Eylon (2003) also stated that systems thinking includes two components which are scientific knowledge and cognitive ability. They also noted that even when the students take the same amount of knowledge, their level of understandings of the systems and relationships could be different since they hold inherent ability that affects their understanding. According to other researchers (e.g., Booth-Sweenety & Sterman, 2000; Draper, 1993), systems thinking consists of cognitive abilities such as thinking in dynamic process, understanding the dynamic complexity, recognizing non-linearity in the system or understanding the stock and flow relationships. Generally, researchers studied understanding of the systems in engineering context. Yet, in SE context, Assaraf and Orion (2005; 2010a, 2010b) studied STS in Earth systems science area. They emphasized that studying Earth systems help students understand natural cycles like water cycle, carbon cycle, energy cycles, interactions among these cycles and their impact on people's lives. The authors developed their own systems thinking hierarchical model and determined eight emergent characteristics of systems thinking in the Earth systems context (Table 2.1). Similar to previous researchers, the authors emphasized cognitive components of systems thinking skills in SE.

Capra (2005, p.20) as a system theorist defined systems thinking as a network of relationships. According to him, living systems are not linear; instead, they include networks and relationships. Therefore, understanding of the world requires a new way of thinking. He described systems thinking in relation to six shifts of perceptions as displayed in Table 2.1. Capra (2005) also emphasized that systems thinking could be integrated into all academic fields like biology, economy or anthropology since all these fields deal with living systems. Moreover, he pointed out that creating a sustainable society systems thinking perceptions is important, and they should be taught to the students in the schools.
As mentioned in the previous section, in ESD context systems thinking has been accepted a key competency as well (e.g., Sleurs, 2008; Sterling, 2003; UNECE, 2011; Wiek, 2011). For instance, according to Sleurs (2008) systems thinking in ESD context is related to changing perspectives, building empathy with people and systemic view of the world.

Nolet (2009), for instance, identified systems thinking as one of the themes of sustainability literacy. According to the author, systems thinking does not only refer to relationships among species, but also connection among social, economic and ecological systems.

Sterling et al. (2005), on the other hand, used linking thinking that has the same meaning with systems thinking. Sterling (2005) mentioned that linking thinking or systems thinking refers to thinking out of the box and understanding relationships among things, events, and Sterling et al. (2005) developed a number of learning and teaching activities related to systems thinking titled as linking thinking activities. For instance, in an example, the question of "How do you see a tree?" was asked. Through this question, the authors emphasized that people hold different views, values and beliefs; therefore, they could see a tree from different perspectives such as a source of food or a source of beauty. People's perspectives influence how they interpret the world (Sterling et al., 2005).

Similarly, in the literature, integral ecology approach also deals with multiple perspectives about understanding the environmental systems. Integral ecology was adapted from Ken Wilber's integral theory (Hargens, 2005). According to Hargens (2005), there is a need to develop our individual consciousness to overcome ecological crisis in the world; therefore, integral ecology emphasizes the link among self (subjectivity), culture (intersubjectivity) and nature (objectivity). That is, integral ecology presents a comprehensive approach to environmental issues. Hargens (2005) notes that this new framework could be integrated to many fields like outdoor schools, urban planning, policy development etc. For this reason, the researcher of this thesis included integral ecology as a component of systems thinking since integral ecology holds a similar perspective with systems thinking. Table 2.1 presents sample systems thinking frameworks in SE and ESD literature.

Indeed, as displayed in Table 2.1, several authors identify different approaches and definitions of systems thinking. Yet, the common point is that systems thinking is defined as a higher order skill. That is to say, systems thinking is not considered as a single skill; instead, it is a combination of other skills or a set of competencies (Assaraf & Orion, 2005; Chandi, 2008).

More recently, systems thinking has attracted the attention of the researchers in education, especially in SE and ESD, and it has been studied in education from elementary level to university level (Lyons, 2014). Hogan and Weathers (2003) suggested that systems thinking skills should be developed in the schools. In SE, for instance, there are a variety of studies in order to develop students' understandings of complex systems, nature of the world and cyclic mechanisms in the Earth (e.g., Assaraf & Orion, 2005; Assaraf & Orion, 2010; Kali et al., 2003; Shepardson, Roychoudhury, Hirsch, Niyogi & Top, 2014). Moreover, in ESD context, various studies have focused on developing systems thinking skills (e.g., Connel et al., 2012; Sandri, 2013; Remington-Doucette et al., 2013; Wiek, et al., 2011). As mentioned earlier, today's problems are more complex and need multiple solutions. Today's solutions could be tomorrow's problems; therefore, students should be equipped with the skills about how to solve the complex problems (Chandi, 2008). SE, for instance, could help students understand complexity of the systems (Assaraf & Orion, 2010). For this reason, individuals' thinking abilities need to be changed. In order to develop students' STS, first, teachers should hold these skills. There are a variety of studies to develop and evaluate STS. The topic of the next section presents these approaches to develop and measure STS in SE and ESD context.

Table 2.1

Systems Thinking Literature in SE and ESD context

The authors	Systems Thinking Definitions/ Frameworks
Assaraf & Orion (2005, 2010 a,b)	The authors determined eight emergent systems thinking characteristics in the Earth science context; 1. The ability to identify components of a system and processes 2. The ability to identify relationships among systems' components 3. The ability to identify systems' components and processes within a framework of relationships 4. The ability to make generalizations 5. The ability to identify dynamic relationships within the system 6. Understanding hidden dimensions of the system 7. The ability to understand cyclic nature of the systems 8. Thinking temporally: Retrospection and prediction.
Capra (2005)	Capra (2005) identified six shift of perceptions related to systems thinking 1. From the parts to the whole; living systems constitute integrated systems, and they cannot be reduced to small parts. 2. From objects to relationships: An ecosystem does not mean a collection of species. It constitutes a community, set of relationships and networks. 3. From objective knowledge to contextual knowledge: Contextual knowledge is related to explaining the things in their contexts or in their environments. 4.From quantity to quality: Understanding that relationships cannot be measured, and they cannot be put on a scale 5.From structure to process: Understanding that systems always evolve, and they are in a change and transformation 6. From contents to patterns: Focusing on the patterns in a living system instead of content of the system.
Sleurs (2008)	Systems thinking as a key competency for ESD educators; • Systems thinking helps individuals understand how to act in a sustainable way. It combines knowledge with wider context. Furthermore, systems thinking is related to values and ethic and help individuals change perspectives and build empathy with other people. Developing a systemic perspective helps individuals feel to be a part of the system.

Table 2.1 (Continued)

The authors	Systems Thinking Definitions/ Frameworks
UNECE (2011)	Systems thinking refers to integrative approach: • Developing an understanding of how today's actions influence tomorrow's choices • Including perspectives related to social, economic and environmental systems • Exploring different cultures and worldviews as a valuable tool • Creating connection among people both locally and globally
Nolet (2009)	Systems thinking as one of the themes of sustainability literacy: • Systems thinking not only refers to relationships in nature but also relationships among social, economic and ecological systems • Understanding that social, economic and ecological systems are interconnected, and they have cyclical patterns.
Sterling et al. (2005)	Linking thinking or Systems thinking: Thinking out of the box, thinking like a web Understanding relationships, patterns among the things and events
Integral Ecology (Hargens, 2005)	Integral Ecology: • Multidimensional thinking • Looking at the issues from holistic perspective • Understanding connection among self, culture and nature. Furthermore, integral ecology holds four dimensions which are experience, behavioral, cultural and systems.

2.5.2 Measuring and Developing Systems Thinking Skills

Systems thinking has been suggested as one of the goals of education to be fostered (Hogan & Weathers, 2003). In the last few years, systems thinking has emerged as a critical skill in SE (Assaraf & Orion, 2010; Batzri et al., 2015; NRC, 2012), as a component of sustainability literacy (Nolet, 2009) and as a required competency to be an ESD educator (e.g., UNECE, 2011). The important point is how to develop and measure STS.

Brandstadter et al. (2012) noted that there is a need to develop appropriate systems thinking measurement tools in educational studies. In the literature, various instruments such as interviews, classroom discussions, written samples or case study analysis and concept maps have been developed and applied in order to assess STS (e.g., Assaraf & Orion, 2010; Brandstadter et al., 2012; Connel, et al., 2012).

For instance, Assaraf and Orion (2005; 2010) evaluated systems thinking skills based on the eight emergent characteristics explained as presented in Table 2.1. In a study, Assaraf and Orion (2005) investigated high school students' development of STS in the Earth system science context. They developed a multidisciplinary learning environment for high school students, and they included both indoor and outdoor activities. They used various kinds of instruments including questionnaires, drawing analysis, word association, concept maps, interviews, factory and hidden dimension inventory, repertory grid and observations. These instruments have been utilized to measure STS especially in the water cycle context. They conducted the pilot study in order to find out whether data collection tools could identify specific STS. For example, the authors developed three Likert type questionnaires to identify students' understanding of dynamic nature of groundwater system, cycling nature of the hydrosphere and components of water cycle. In addition to interviews, the authors wanted students to draw the water cycle in order to explore components of the system, relationships, the human aspect and the cycling perception of water cycle. They also used interviews for data collection and interviews provided to evaluate students' conceptual change during the learning process. In addition to interviews, concept maps allowed the researchers to explore how students show relationships among the components. They evaluated concept maps based on the number of concepts, relationships and cycles. In the factory inventory, the authors used factory assignment interviews which were related to deciding whether to build a factory or not. This task was found difficult by the participants, and the authors decided that prediction and retrospection (temporary thinking) could be the most difficult characteristics of systems thinking. The results revealed that students displayed a meaningful development in STS, and they reached to highest level of STS in the water cycle context.

In a further study, Assaraf and Orion (2010a) investigated four students' (four cases) STS development for six years. They again examined systems thinking perceptions in the water cycle context. They collected systems thinking characteristics in three levels as analysis of system components, synthesis of system components and implementation, and they arranged these characteristics in a hierarchical pyramid model. The authors used a series of data collection tools which are observations, interviews, concept maps, drawings etc. These tools measured specific STS. For example, they used a cycling thinking questionnaire to reveal students' understanding of the cyclic nature of the Earth systems. They conducted interviews at the beginning, in the middle and at the end of the learning process. Interviews were used to get in the deep information. They asked questions related to students' drawings in the interviews such as explaining the components of the water system. The authors concluded that the results supported their claim of the hierarchical structure of the STS as students first achieved lower thinking skill, and then they reached to higher level thinking skills. Moreover, each student showed different level of development, but they developed their systems mental models over time.

Interviews have been used as a major tool to measure STS in education literature. In general, researchers used interviews along with questionnaires, drawings or concept maps to get detailed information. For instance, in a recent study conducted by Batzri et al. (2015), data were collected both quantitatively and qualitatively. The authors measured two systems thinking characteristics- dynamic thinking and cycling thinking of undergraduate students who took geology and Earth system courses. First, they conducted quantitative part of the study, and they collected data through an Earth system questionnaire, and secondly, they asked students to explain their answers in the questionnaire. Thus, through interviews the authors aimed to identify how students express their dynamic and cycling thinking. The results of the study revealed that geology students showed higher level dynamic thinking and cyclic thinking after the course. The authors suggested that developing STS of undergraduate students in all fields like economy, natural science, and social science is critical in order to understand the Earth's complex system. In addition, teaching students Earth science helps them understand components of the system, interactions, cycles, patterns and hidden dimensions (Batzri et al., 2015; Hmelo-Silver & Azevedo, 2006).

In another study implemented by Chandi, Reid, Mcwilliam and Gray (2009) was related to investigating university students' opinions about a system based model and its use in learning and teaching biology. The researchers developed a model in order to help students to understand the whole system, components and connections in the system based on the transportation context. They used the elements of systems thinking which are the levels, the whole, the parts and the links in the model. Implicitly, the researchers aimed to develop systems thinking skills of university students. They collected data both qualitatively and quantitatively. First, they used a self-administered questionnaire to get students' opinions of the systems model. Later, they asked students to discuss and express their opinions about the usefulness of the systems-based model for understanding transportation of the corn seed. According to results of the study, the systems based model helped students understand biological systems in a comprehensive way. The authors suggested that this model has potential in biology education context in order to prevent fragmented learning while teaching complex systems.

Again in biology education, Hmelo-Silver et al. (2007) conducted research examining understandings of novices (pre-service teachers and middle school students) and experts (biologists and hobbyists) in the context of two complex systems- human respiratory system and an aquarium ecosystem. They focused on differences between novices and experts in understanding of the two complex systems. The researchers collected data through drawings and interviews related to human respiratory system and aquatic ecosystem. In particular, they asked participants to draw anything they think in an aquarium and parts of human body involved in breathing. Later, interviews including open ended questions and problems were conducted to reveal participants' knowledge. The researchers analyzed data based on structure behavior function model which is related to understanding complex biological systems. The results of the study revealed that understanding structures are easier than functions or behaviors for novices. On the other hand, the researchers found differences in terms of different kinds of experts' representations of complex systems. Particularly, the results revealed that pre-service teachers and middle school students showed similar mental models in understanding of complex systems. The researchers claimed that teachers hold limited understanding of complex systems since they have not taken part in any significant science instruction for understanding complex systems in their college education. As teachers have limited understanding of complex systems, they have difficulty to teach these systems to their students. Therefore, researchers suggested that just like students, pre-service teachers also need to learn about complex systems in their education.

In another study conducted by Dutton-Lee (2015), interviews and questionnaires were used to measure STS. Dutton-Lee (2015) conducted a dissertation study for exploring science teachers' STS. She focused on elementary in-service and pre-service science teachers' understandings of complex systems and their knowledge of systems thinking in water cycle context. The researcher used the components of systems thinking which are hidden dimensions, understanding the relationships/interactions are and identifying components and processes. Data were collected through questionnaires and semi-structured interviews. In order to analyze data the researcher developed systems thinking rubric including levels from novice (0) to intermediate (4). The results revealed that both in-service and pre-service science teachers experienced difficulties in developing several aspects of systems thinking which are identifying components and processes, identifying multiple relationships and hidden dimensions of the system and recognizing the human impact on the system. Teachers' skills have been found in the novice and recognition level in terms of identifying components and process of the water cycle. Furthermore, teachers could not identify multiple interactions among the atmosphere, biosphere, geosphere and hydrosphere. That is to say, in-service and pre-service science teachers struggled to recognize multiple relationships in the complex systems, and this indicates that teachers lack systems thinking. Moreover, the researcher explored that teachers could not identify invisible components of the system (hidden dimensions) and they showed lack of understanding of human impact on the complex systems (e.g., water cycle). For instance, teachers struggled to explain the impacts of global warming and population growth on the water cycle. As a result, Dutton-Lee (2015) suggested that teachers need to have STS and learn how to teach these skills to their students. Therefore, teachers need effective pedagogical approaches to learn and teach systems thinking (Dutton-Lee, 2015).

Maxwell (2009) on the other hand, studied on science-sustainability relationships and systems thinking. The researcher noted that in order to use sustainability contexts for teaching science, there is a clear need to have systems thinking in education. For this reason, the researcher developed a learning resource based on the science-sustainability relationship and examined the results of the implementation of this learning resource on students and science teachers' resilience and decision making. The researcher developed a project named "Take-Make-Waste" consisting of 21 lessons. Students found an opportunity to explore different views, values, and traditions, local and global use to make decisions in three steps: "Take, Make and Waste" (p. 230). This learning resource was developed based on systems thinking, particularly addressing the human-nature relationship and the science and sustainability relationship. The researcher collected data through pre-test, post-tests and interviews. The results revealed that teachers expressed there is a need to clarify the intent of sustainability education and the ways for integrating sustainability into their courses.

Concept map is another tool frequently used for measuring STS. Sommer and Lucken (2010) suggested that concept mapping could be a useful tool to evaluate STS. Concept mapping has been used in a number of studies in SE (e.g., Brandstadter et al., 2012; Raved & Yarden, 2014; Tripto, Assaraf & Amit, 2013).
For instance, Raved and Yarden (2014) studied 7th grade students' STS in the context of human circulatory system. They developed learning activities based on the systems model in order to develop STS of students. Later, they asked students to create components and processes in the human circulatory system and draw a concept map by connecting the components and processes. The authors evaluated students' concept maps based on their model including four components of systems thinking development which are "The ability to identify components in the system", "The ability to identify simple relationships between the system components","The ability to identify dynamic relationships between the system components", "The

ability to organize the system's components in a framework of interactions" (p. 6). The authors analyzed concept maps according to number of components, dynamic relationships and interactions. They concluded that there was an improvement in the skills of identifying components and simple relationships in human circulatory system.

A recent study about using concept mapping to measure systems thinking was employed by Tripto, Assaraf and Amit (2013). They examined the effectiveness of concept mapping to reveal a detailed picture of STS of high school students. They tested the effectiveness of concept mapping in the context of the human body system. They explored students' difficulties of understanding the human body system in their concept map drawings. The results showed that concept maps were powerful tools to describe the first two levels of systems thinking (analysis and synthesis), but they were not useful to reveal the highest levels of skills (students' understanding of patterns and thinking temporary). It is understood that concept maps could be useful to assess lower level of thinking skills.

In another study, Safayani, Derbentsava and Canas (2005) noted that cycling concept maps could be useful tools to determine functional and dynamic relationships among the concepts. The authors claimed that showing both static and dynamic relationships in one concept map could be more powerful to represent a system. Cycling concept maps could show interdependencies or how a system works. Furthermore, understanding dynamic relationships and cycling nature of the system are characteristics of STS suggested by Assaraf and Orion (2005). Assaraf and Orion (2005) note that Earth system science includes the approaches related to cycling system in the world (interactions among biogeochemical cycles-geosphere, hydrosphere, biosphere and atmosphere). Moreover, people are part of nature and they should act in harmony based on the laws of cycling system (Orion & Ault, 2007 as cited in Assaraf & Orion, 2010a). In the biological systems, cycling representations are crucial because biological systems work in cycles (Bertalanffy, 1972 (as cited in Safayani et al., 2005). Therefore, cycling maps are important since they represent dynamic functional relationships among the concepts in a system and enable students to indicate how components of a system work together (Safayani, et al., 2005). Cycling relationships constitute the basis of systems thinking. An example model of cycling maps adapted from Safarani et al (2005) was presented in figure 2.1.

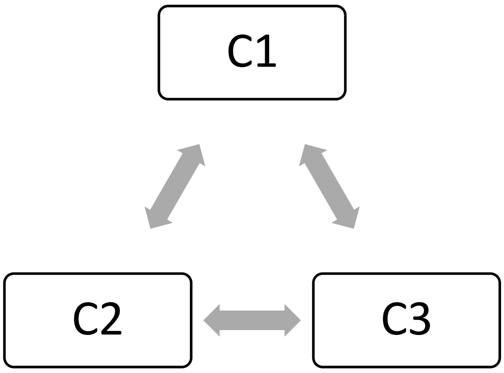

Figure 2.3 Cycling map of interrelationships among C1, C2, C3 (Safarani et al., 2005)

Assaraf and Orion (2005) also encouraged their students to draw non-hierarchical maps in order to reveal complex relationships among the concepts since the complexity of the systems could not be indicated in hierarchical maps.

As understood from the literature, the nature of systems thinking is based on the dynamic, complex relationships and cycling relationships in a system; therefore, cycling concept maps could be a useful tool to demonstrate the components and complex relationships in a system.

In addition to interviews and concept maps, written samples, essay or case studies are other tools mostly used to measure STS. In higher education, written samples or case studies and using rubrics are seen as the most feasible approaches to assess STS (Wang & Wang, 2011; Zulauf, 2007).

For example, Shepardson, Roychoudhury, Hirsch, Niyogi and Top (2014) investigated seventh grade students' understanding of a complex system based on systems thinking research. The researchers collected data through written responses of students. They examined writings of the students related to their conceptions of climate system. They used three written prompts to reveal students' responses such as asking students how climate is influenced by the components of a climate system. The authors adapted systems thinking framework of Assaraf and Orion (2005) to climate system. The results revealed that students could not recognize multiple relationships among the components of the climate system and they identified a climate system based on linear cause-effect relationships. For instance, students struggled to make connections between atmosphere and other components of the climate system. The researchers suggested that science and climate educators should educate teachers to develop a systemic understanding of the climate system and prepare teachers to teach their students the climate system.

Case studies have been used especially in ESD context. The aim of the case studies is to develop students' problem solving skills through engaging them in real world challenges. Thus, students could understand other people's perspectives and interests (building empathy) (Remington-Doucette et al., 2013). Moreover, case studies help individuals to cope with wicked sustainability problems by realizing that solution also depends on other people's values, perspectives, beliefs (Skarbuskis, 2008). Case studies also have been used as a tool to measure STS.

For instance, Connell et al. (2012) measured STS of the undergraduate students through case studies (pre and post intervention). These case studies given to students were related to several sustainability challenges of industrial firms. For each case study, students were asked several questions related to case such as identifying possible environmental, social and economic dimensions or identifying challenges among these dimensions. The authors also developed a rubric in order to analyze students' responses in the case study analysis. The rubric included two components which are holistic thinking and conflict resolution and a scale from 0 (no skill) to five (exceptional skill) in order to evaluate the quality level of students' responses in the case study. Results revealed that students who attended in an intervention including a holistic and integrated approach developed their systems thinking skills. After the intervention, students were able to think sustainability issues from multiple perspectives. Therefore, the authors suggested that there is a need to integrate systems thinking into a course or whole curriculum to foster STS of the students.

A similar study conducted by Remington-Doucette et al. (2013) aimed to measure key competencies (including systems thinking) of undergraduate students before and after a sustainability course. Students from different majors like economy, sociology and landscape architecture took part in the course, and they learnt about the functions of the complex systems in the course and how to become sustainability problem solvers. Researchers collected data at the beginning and at end of the semester through two case studies focused on typical sustainability challenges. The authors specifically measured several elements of systems thinking: students' ability to analyze complex systems in terms of sustainability aspects (social, economic and environmental) and ability to identify values behind individuals' actions.

Furthermore, in order to analyze case studies, researchers utilized the rubric that they had developed before. The results of the study indicated that the sustainability course contributed to development of students' STS, particularly their ability to think holistically about sustainability issues. However, students struggled to identify conflicts and propose solutions to solve these sustainability conflicts.

As mentioned above, rubrics have been frequently used to evaluate STS levels of the individuals. For instance, Hung (2008) administered a study with graduate students and collected data both qualitatively and quantitatively. Students attended a seminar class related to systems thinking, and pre-test and post-test have been used to measure STS of students. The author developed a set of rubrics in order to evaluate students' systems thinking development process. In particular, several cognitive characteristics of systems thinking have been measured in the study such as identification of crucial variables, interconnectivity and cause-effect relations. Based on the results of the study, after one semester systems thinking course, students developed their skills. Particularly, students used several systems thinking items such as interrelationships, interconnections, and wholeness in their explanations. The authors suggested that in order to improve systems thinking practice of the students, it is necessary to conduct an instruction about systems thinking.

The understandings generated from the brief literature review of systems thinking skills display that systems thinking has been studied in a variety of contexts such as Earth system science, biology, geology, ecology and sustainability and in a variety of education levels from elementary to university level. A series of measurement tools have been used to assess STS. Researchers utilized from both qualitative and quantitative data collection methods. Especially, qualitative data collection tools like interviews, concept maps, and written samples (essays) or case studies have been preferred by the researchers in order to get enriched data about STS of the students. In general, systems thinking have been evaluated in a specific context and through specific courses (e.g., sustainability course, biology course). Furthermore, researchers developed tools to measure specific STS, and they usually developed a structured rubric to evaluate the skills (e.g., Connel et al., 2012; Hung, 2008; Remington-Doucette et al., 2013). In SE context, researchers especially focused on students' understandings of the complex systems, identifying components, hidden dimensions and interactions in a system. They mostly studied STS in Earth science, climate science, and geology and biology contexts. In the ESD context, researchers focused on how students could identify aspects of sustainability and analyze sustainability conflicts, and they usually utilized case studies to evaluate students' STS.

2.5.3 Implementation of ESD for Developing Systems Thinking Skills

This thesis focuses on the argument that ESD has an integrated and holistic approach, and cooperation between ESD and SE could be effective to develop STS of PSTs. In particular, outdoor ESD model has been suggested to foster STS of PSTs to become an ESD educator.

In general, today, there are still not enough efforts for reorienting teacher education for sustainability. Mckeown (2012) points out that ESD is not a part of initial teacher education programs and teachers' professional development. Wals (2009) reported that although there is an increase in ESD tools and materials, there is still lack of study to implement ESD. Similarly, Nazir, Pedretti, Wallace, Montemurro and Inwood (2011) note that there is a gap between research, policy and practices for ESD despite many efforts have been spent through the years. Therefore, in the final report of DESD (UNESCO, 2014), it is noted that more work is necessary to transform teacher education in terms of ESD learning and teaching methods.

What kinds of learning and teaching methods are necessary for ESD? Littledyke and Manolas (2010) argued about pedagogies for ESD, and they pointed out that these pedagogies should be related to real life experiences. For this reason, as Mckeown (2012) suggested, today's pedagogies related to ESD should be more participatory and action-oriented in order to engage learners with sustainability solutions and cooperative working in the community (Mckeown, 2012). Moreover, Sterling (2004) argued that sustainability is not an issue to be integrated into curriculum; instead, it is related to a different view of curriculum and pedagogy. That is, Sterling (2004) emphasized a transformative, integrative and systems thinking approach for sustainability education in higher education.

In the literature, there are several attempts to incorporate SE and ESD in order to develop competencies of science teachers (including systems thinking). More specifically, researchers emphasized different aspects of systems thinking such as identifying aspects of sustainability and relationships among them, identifying elements of natural system or developing sense of place in their studies, and they used different learning and teaching methods for ESD.

For instance, Foley et al. (2015) designed a sustainability science course to foster sustainability literacy of pre-service science teachers. They used online sources, digital story telling activities to teach sustainability topics. The authors integrated a framework including four ways of thinking which 1 are ”Future Thinking”, ”Values Thinking”, ”Systems Thinking” and ”Strategic Thinking”. They specifically measured pre-service teachers' definitions of sustainability through a questionnaire and using concept maps. The authors concluded that pre-service teachers developed their sustainability definitions from simple to more complex level through the course. Furthermore, at the end of the course, pre-service teachers realized their responsibility to achieve a sustainable future (Foley et al., 2015).

In another study conducted by Burmeister and Eilks (2012), both students and teachers developed their higher order cognitive skills, and they started to think about their personal decisions for sustainability. Burmeister and Eilks (2012) focused on implementation of ESD in chemistry education. They asked open ended questions related to implementation of lesson plans. As a result, both students and teachers described lessons plans as highly motivating and helped students learn sustainability topics and be more critical about the use of chemical products in their life.

Similarly, another study related to implementation of ESD was conducted in chemistry education by Karpudewan, Ismail and Mohamed (2008). The researchers investigated the impact of laboratory-based green chemistry course on student teachers' (in science education program) understandings of sustainablity concepts. The researchers collected data through questionnaires and interviews. The results revealed that green chemistry course developed students' understandings of sustainability concepts and also their communication, problem solving and decisions making skills. Furthermore, student teachers learnt about the relationships among social, environmental and economic aspects. They also started to realize their responsibility for preserving the local and global environment and the whole ecosystem. Ultimately, this course influenced student teachers' behaviors to create a sustainable lifestyle.

Another study conducted by Wyner (2015) focused on the development of pre-service and in-service science teachers' understandings of systemic connections among ecological, economic and social aspects of sustainability during an environmental science course. The author designed the course based on two themes which were Aldo Leopold's Land Ethic and the Ecology Disrupted Model. The aim of the course was to teach students to explore how they are part of an ecological (land) community. The course consisted of case studies including social, economic and ecological aspects of sustainability. In particular, ecology disrupted model helped students see hidden dimensions and human impact on the ecosystems. The results revealed that the course helped pre-service and in-service teachers explore connections among social, economic aspects of sustainability and their connections with the ecological community.

In accordance with ESD, implementations outdoor education is also described as an important learning and teaching method. For a long time, researchers around the world have been calling for the importance of human-nature relationship, place, social justice and ecological perspectives in outdoor education (Hill, 2012). Beames et al. (2012) note that outdoor education could develop a broad understanding to create a sustainable future and provide a rich learning environment to understand complex systems and relationships among them. For example, the relationships between plants and animals, flow of energy and cycling of nutrients and human impact on these systems could be understood well through outdoor education (Beames et al., 2012). Furthermore, Assaraf and Orion (2005) emphasized that while studying a natural phenomenon, outdoor education should be integrated into curriculum as much as possible. Outdoor education has been also found as effective to develop STS of the individuals (Assaraf & Orion, 2005, 2010b).

Several studies focused on outdoor education in ESD and SE context. For instance, Garner, Siol, Huwer, Hempelmann and Eilks (2014) developed innovative practices for ESD in chemistry education, and they put out-of-school visits at the center of their study. They implemented modules incorporating formal and non-formal learning environments to teach sustainability issues. They collected feedbacks from both students and teachers related to modules. According to results, both teachers and students' feedback related to course were positive. Teachers expressed that out-of-school visits increased students' motivation and interest towards green chemistry.

In an ESD context, Hill (2012) developed a pedagogical approach towards outdoor education by incorporating sustainability issues and practices. The author presented a sustainability-focused outdoor education model and conducted research with a group of teachers. Teachers transformed their outdoor education programs through integrating sustainability concepts and principles. The author conducted interviews with teachers to evaluate their programs. The results revealed that a small group of teachers expressed several changes related to sustainability and outdoor education. These changes were related to philosophy, values, programming, teaching and learning strategies. Hill (2012) reported that teachers developed their sustainability understanding and action competence (taking action for sustainability) through outdoor education.

Another study related to outdoor based ESD was conducted by Carney (2011). The author investigated pre-service and in-service teachers' knowledge, skills and dispositions related to sustainability through a field study- working in a garden. Furthermore, he explored to what extent pre-service and in-service teachers integrate sustainability principles into their teaching practices. The researcher collected data by means of online survey, focus group, semi-structured interviews, and observation of teacher workshops and analysis of teacher work samples. Results of the study revealed that teachers expressed their willingness to teach sustainability principles in their classes. Two teachers were able to integrate sustainability into their classes. One of the teachers incorporated garden work into science class and aimed to develop skills of identifying components of a system and interactions among them which are related to systems thinking. Carney (2011) noted that although in-service and pre-service teachers find it important to teach sustainability, they expressed that there are several barriers to incorporate sustainability into the curriculum. Therefore, the authors implied that there is a need to explore more approaches for professional development of teachers to teach sustainability.

In a further study, O'Brien, Sparrow, Morales and Clayborn (2015) investigated the effectiveness of a sustainability-focused science method course on pre-service teachers' science teaching self-efficacy. The authors redesigned science methods course based on the sustainability literacy themes of Nolet (2009) and Cloud Institute Education for Sustainability Standards. Two frameworks included systems thinking and interdependence themes, and these themes were also integrated into the course. Place-based field trips were also included in the course. Data were collected both qualitatively and quantitatively. The results revealed that the course contributed to pre-service teachers' development of their professional development related to ESD.

Sense of place that was defined as a component of systems thinking in the current study has been investigated by a number of researchers in ESD context. According to Moseley, Desjean-Perrotta and Kharod (2015), attachment to a place is important because individuals who feel connected to a place will probably care and protect the place. Therefore, sense of place, which is a multidimensional and complex concept, is important to grow environmentally responsible citizens (Moseley et al., 2015). Moseley et al (2015) conducted a study of pre-service teachers' definitions of a sense of place. Pre-service teachers who enrolled in an undergraduate course, called Science and Humanities, were the participants in the study. Qualitative data were collected through written narratives and digital stories. Researchers analyzed data according to Ardoin (2006)'s multidimensional sense of place framework which included four dimensions-biophysical, psychological, political and sociocultural. They discovered that pre-service teachers focused on three dimensions in their definitions. These dimensions were biophysical, psychological and sociocultural. The political dimension was not revealed in their definitions.

Furthermore, most of the participants did not express their connection to a place from a natural perspective: instead, they described their connection to building environments (e.g., church). In addition, they described a sense of place from more psychological (individual) elements. Therefore, the researchers argued that sense of place needs to be evaluated with the broader lens of ESD including multiple dimensions. Furthermore, researchers suggested that teachers need to give opportunities to their students to experience, explore and discover their local places. Not only learning in local settings but also multidisciplinary knowledge about local communities (cultural, political etc.) should be integrated into teacher education programs (Moseley, et al., 2015).

In the literature, the authors focused on outdoor education in order to foster a sense of place of individuals. Especially, researchers emphasized place-based outdoor education. For instance, Semken and Freeman (2008) conducted research to investigate the sense of place of students who participated in a place-based geology course including field trips and cases in the geological and cultural context. They collected data through questionnaires to look for changes in students' place meaning and place attachment. The results revealed that students developed their sense of place in the course (their attachment to the place and rich meanings for the place such as geologically and culturally).

In a further study, Semken, Freeman, Watts, Neakrase, Dial and Baker (2009) examined factors that influence the sense of place of students through place-based geoscience teaching. The data were collected from undergraduate students through surveys. The results showed that visiting a place frequently (out of school visits) positively influenced students' emotional place attachment and production of richness of meaning (sense of place).

Recently, several researchers (e.g., Assaraf & Orion, 2005, 2010; Keynan et al., 2014) asserted that systems thinking is a key outcome of outdoor education. For instance, in a recent study, Keynan et al. (2014) investigated the influence of a place-based outdoor learning on high school students' systems thinking skills in ecology context. They used repertory grid as a systems thinking measurement tool. The results revealed that through the course, students developed their systems thinking skills to high levels. The authors claimed that field trips contributed especially to the development of temporary thinking (the relationship between present and future) as a component of systems thinking. Furthermore, through field trips, participants developed a more complex systemic understanding of the local environments.

In the literature, it is understood that outdoor education in ESD could contribute to developing STS of the individuals. The relationship between ESD and outdoor education is described by Higgins and Kirk (2006) with the following statement "Feeling water in the rain or sitting on a river in a canoe are opportunities for students to discuss water cycle and make relationship with global climate change or while students boil water by using a camp stone or fire, they can discuss the storage and release of carbon from wood; and thus, global carbon balance including environmental, social and economic dimensions" (p.321). This statement reveals that outdoor education helps individuals make connection among the many components of a natural system and thus, enhance students' systems thinking.

Moreover, Lugg (2007) claims that through outdoor education, individuals develop their connections with nature and their alternative worldviews for sustainable living. As a result, outdoor education contributes to developing sustainability-literate citizens.

2.6 Lessons Learnt and Summary of the Literature Review

Today, we face wicked problems which are complex and including multiple dimensions and unpredictable results. In the education literature, researchers argue about how to cope with these wicked problems to create a sustainable future.
In the 21st century, many researchers questioned the role of SE. A number of researchers note that the mission of SE should be to help students have a broad worldview, be interested in social and global problems which are mostly related to scientific issues, develop an integrated understanding of big ideas and a fundamental shift towards systems thinking (e.g., Carter, 2008; Choi, et al., 2011; Maxwell, 2009; Tytler, 2007).

Moreover, today ESD is seen as a visionary approach to help people understand the natural systems, developing a wider perspective to deal with the complex problems that threaten our future. For this reason, it is crucial to integrate ESD into SE. In the recent literature, there have been many attempts to increase cooperation between ESD and SE and to educate science teachers for sustainability. Nevertheless, it is not enough to integrate sustainability into SE programs. We need competent science teachers for ESD. In the light of the literature review, the central argument of this study is how to educate science teachers as ESD educators. In order to find an answer to this question, the researcher asserted that there is a need to develop STS of PSTs and outdoor-based ESD course could be an effective model to develop STS.

For this reason, the literature review started with the evolution of SE from the past to present and the transformation related to interpretation of science and SE. The literature continued to explore the history of ESD and the need for ESD in the current times. In these sections, the link between ESD and SE has been examined, and how systems thinking was recognized as a critical skill for both ESD and SE was mentioned. This section provided strong arguments why we need ESD type SE in this century and why we need to develop STS of PSTs. Based on the arguments, systems thinking has been put forward as a core competency to become an ESD educator. The next section focused on developing and measuring STS in SE and ESD contexts. As understood from the literature review a variety of measurement tools (from interviews to concept maps) have been developed and these tools were prepared based on the specific contexts such as biology, geology, Earth science, ecology or sustainability and assessed specific systems thinking characteristics. Furthermore, it is explored that sustainability-focused instructions helped individuals foster STS. Moreover, the literature review indicated that systems thinking in SE has more focused on understanding complex systems, revealing components of the system, hidden dimensions and interactions in the systems. That is, these studies emphasized cognitive abilities related to systems thinking. Yet, in ESD context, researchers addressed several STS such as building empathy with people, considering values and ethic. In addition to cognitive abilities in ESD context, affective components of systems thinking were included. Furthermore, researchers frequently used case studies to evaluate STS of the individuals in ESD context. The literature review continued to report implementation of ESD for developing STS. In the literature, there is not sufficient research to investigate methods of ESD for developing STS. Therefore, studies from different fields have been also included. In addition to indoor activities for ESD, outdoor education, out of school activities and place-based activities gained importance to develop STS and other competencies related to ESD. In particular, more recent studies have addressed that outdoor education could be helpful to foster STS of the students (e.g., Keynan et al., 2014)

In the literature, it is difficult to find specific studies on the context of SE, ESD and systems thinking. There are separate studies related to systems thinking in SE, systems thinking in ESD or the relationship between SE and ESD. However, there are strong arguments emphasizing that systems thinking is necessary today more than ever in order to solve current complex problems, meet the demands for 21st century to build and maintain a sustainable sociey (e.g., Maxwell, 2009; Senge, 1990; Sleurs, 2008). Therefore, the current thesis could make an important contribution to the SE, ESD and systems thinking literature. Figure 2.3 presents the summary of the literature review.

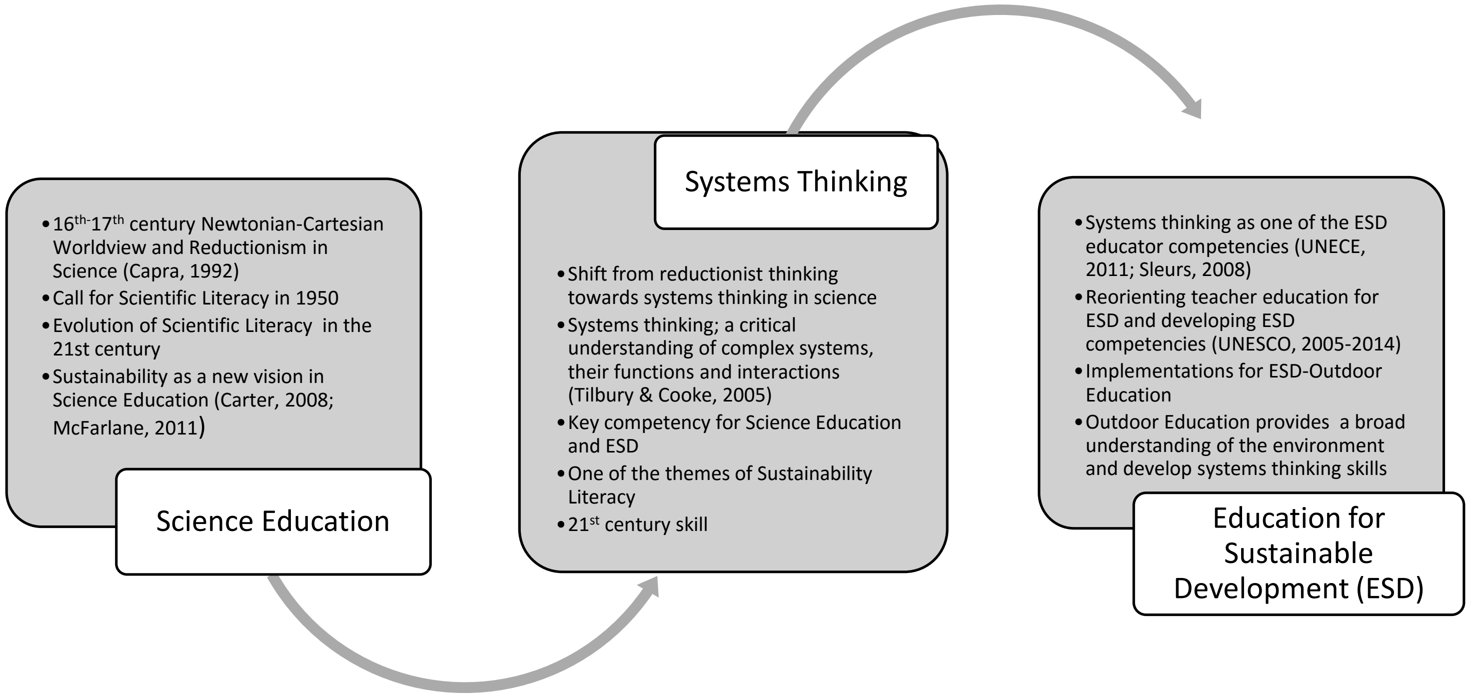

Figure 2.4 Structure of the Literature Review

CHAPTER 3

METHODOLOGY

This thesis aimed to investigate how science teachers could become ESD educators. The current chapter presents information related to research design, data collection tools, data analysis, trustworthiness and limitations related to the study.

3.1 Theoretical Perspective

The thesis is based on the major paradigms that define the worldview of the researcher and perspectives that structure and organize the qualitative research (Denzin & Lincoln, 2005). Among the major paradigms (positivism, post positivism, constructivism and participatory paradigms) reported by Denzin and Lincoln (2005), the one accepted in the current study is constructivist paradigm. Constructivism deals with multiple realities and their implications constructed by the individuals. Accordingly, in the current study, researcher examined how participants develop their STS in a course. In addition to the major paradigms, however, there are other worldviews defined as mechanistic/linear and organic/systems (Patton, 2002, p.119). Organic/systems worldview is related to holistic epistemology, ontology, action and relationships among them (Sterling, 2003). Therefore, it is important to bring systems perspective to qualitative inquiry in order to understand complex systems in the world. The challenge of systems thinking can be explained by the following story: Nine blind people come across an elephant and they identify the elephant by touching different parts of its body. One touches the ear and says it is like a fan. Another touches the trunk and says that is like a snake. The other one touches the whole body and resembles it to a wall. Each blind man touches a different part of the elephant and generalizes to the whole. This tale shows that we cannot understand the whole picture by only bringing all the parts together. To understand the elephant it must be seen in its natural ecosystem in interaction with other parts of the system as well (Patton, 2002). Dealing with STS as a need for science teachers to become ESD educators, this thesis brings multiple approaches, perspectives along with SE, ESD, outdoor education and systems thinking, and therefore, the study holds constructivism as a major paradigm with the systems worldview.

3.2 Researcher Position

The researcher of this study had a background in SE and ESD. She earned her bachelor's and master's degrees in elementary science education. She studied specifically environmental education in her master's thesis. She is also a research assistant at the Department of Elementary Science Education. She has been assisting the departmental courses related to environmental science and sustainability for five years. During her PhD program, she attended several conferences, workshops and summer schools about outdoor education, environmental education and ESD. Moreover, she was involved in several activities related to nature observation, outdoor education, permaculture, ecological farming, sustainable university and sustainable schools in her personal life. The basic idea behind this study is the researcher's belief which underlies that reasons of all the problems in the world are related to our view of the world. That is, our worldviews strongly influence our actions. We need a holistic way of understanding to find sustainable solutions in our lives. However, current education system does not adopt an integrative or holistic approach and does not encourage students to see the big picture in the system. Therefore, the researcher wanted to contribute to ESD and SE research agenda to integrate systems thinking perspective into current education system. Researcher believes that bringing systems thinking and ESD together can play transformative role in individuals' life for sustainability.

3.3. Research Design

The study was conducted in five stages as gap analysis, developing/adapting STS measurement tools, outdoor ESD course development, pilot implementation of the tools and the outdoor-ESD course and the main study (case study). Gap analysis is the preliminary stage of the thesis that aims to compare competencies of ESD educator and science teachers and to explore the gap between them. The second stage of the thesis is based on the outcomes of the gap analysis where systems thinking is the required competence for science teachers to become ESD educators. The second stage is, therefore, comprised of investigating and developing STS measurement tools. The third stage is about outdoor ESD course development in order to develop STS of PSTs. The fourth one is about a pilot study including assessment of the developed STS measurement tools by means of measuring the skills of a group of PSTs as well as piloting the outdoor-ESD course. This stage was also used to get an initial idea on the current level of STS of the PSTs. Thus, the results of the four stages provided a baseline for the main study and allowed the researcher to build the frame of the main study. Subsequently, main study was employed in order to develop STS of PSTs to become ESD educators. Figure 3.1 shows the structure and the stages of the research design of this thesis.

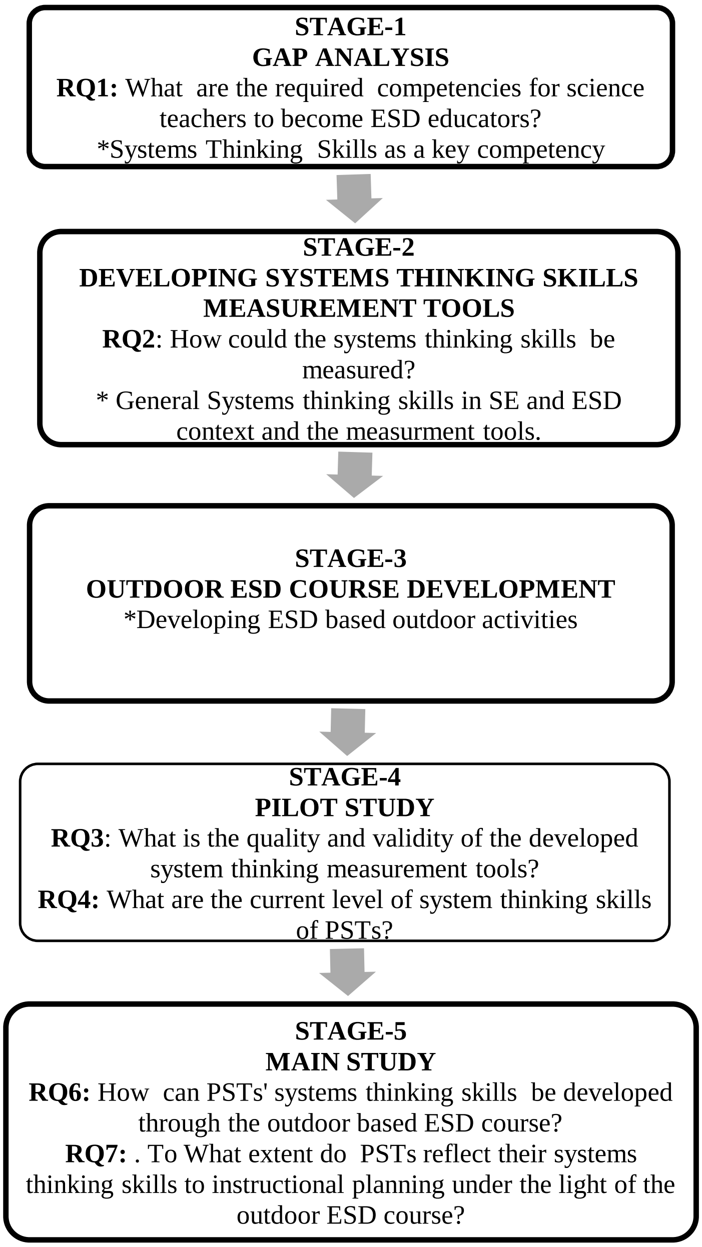

Figure 3.1. Stages of the research design and related research questions

3.3.1. Stage 1: Gap Analysis

3.3.1.1 Introduction

Gap analysis approach is used to determine the difference between what we are doing (current knowledge, practice or skills) and what we should do (Janetti, 2012). Gap analysis was employed in this thesis in order to answer the first research question: "What are the required competencies for science teachers to become ESD educator"? The implementation of gap analysis was realized in two parts as theoretical and tangible. In the theoretical part, competencies (detecting the gap) was constructed based on the literature review (determining the need), and in the tangible part, interviews with ESD and SE researchers were carried out to support the outcomes of the theoretical part. Four stages adapted from Janetti's (2012) study were utilized in the gap analysis process (see table 3.1)

Table 3.1
The Steps of Gap Analysis Process

1. Theoretical Part	2. Tangible Part
a. Determining the need: Examination of the relevant literature related to the competencies for Science teachers (Nezvalova, 2007; NSTA, 2012; NRC, 2012; MoNE, 2008) and ESD educators (UNECE, 2011). *b. Detecting the gap:* Construction of the comparision tables for similarities and differences between science teachers and ESD educators' competencies.	d. *Verifying the theoretical part - interviews with ESD and SE researchers:* Interviews with ESD and SE researchers on the required competencies for science teachers to become ESD educator. Interview results were compared with the outcomes of literature review. e. *The final decision:* Systems thinking skill as a key competency to be investigated.

3.3.1.2 Participants

For the tangible part of gap analysis, five participants (1 male, 4 females) who had a Bachelor's Degree in elementary science education, had a teaching experience as a research assistant in elementary science education and conducted a research on EE and ESD (PhD students) were selected on purpose.

3.3.1.3 Data Collection Procedure

Data collection procedure was carried out through literature review and semi-structured interviews for the theoretical and tangible parts of the gap analysis respectively. For the theoretical part, data collection was completed through examining the literature related to ESD and SE competencies, and hence exploring the required competencies for ESD educators and science teachers. For the tangible part, semi-structured interviews were conducted in order both to support the results of the former part and to explore the current situation in Turkey in terms of competencies for ESD and STs in the words of the ESD and SE researchers. The interview questions for the tangible part were prepared by the researcher and examined by two experts, one being the supervisor of the researcher and the other being an expert in ESD. The three questions asked to the five participants were as follows:

1. What is your opinion on the competencies that science teachers should have in the 21st century?
2. What competencies do you think a science teacher should have to become an ESD educator?
3. What is your opinion on Turkish science teachers' position in being an ESD educator in terms of the required competencies?

3.3.1.4 Data Analysis

Theoretical part of gap analysis was performed through the approach presented in Table 3.1 (Janetti, 2012). In other words, firstly relevant literature was examined, and the competencies for STs and ESD educators were compared in order to determine the gap. For the tangible part, content analysis was used in order to analyze the interviews with the five participants. In content analysis, researcher determines the categories before the analysis begins (Fraenkel & Wallen, 2006). Accordingly, the competencies of STs and ESD educators explored through the theoretical part of gap analysis constituted the categories of the content analysis; however, additional categories emerged during the analysis.

Data analysis for the gap analysis provided the researcher with the required competencies for science teachers to become ESD educators. Systems thinking skill arose as a key competency. In order to measure systems thinking skills of PSTs, the researcher investigated the characteristics of systems thinking especially in ESD and SE context. Based on the literature review, twelve systems thinking skills have been determined and reviewed by five researchers specializing on ESD: one being the researcher's supervisor and the other four being the researchers studying and experienced in ESD studies. After the revisions, twelve systems thinking skills were decided as requirements to become ESD competent science teachers. In the following section STS and measurement tools are presented.

3.3.2 Stage 2: Development of the Tools for Measuring STS

3.3.2.1 Systems Thinking Skills (STS)

Twelve STSs determined as the requirement for science teachers to become ESD educators constitute the heart of this thesis. The first skill, identifying aspects of sustainability (STS-1), has been identified based on the principles of sustainability and ESD (e.g., Mckeown, 2002; Nolet, 2009). The relationships and interconnections are important in sustainability, and they are key concerns of systems thinking (Sterling et al., 2005).

The second skill, seeing nature as a system (STS-2) has been determined based on the integral ecology approach which was introduced in the light of Ken Wilber's integral theory. Integral ecology as a single framework provided a comprehensive understanding of eco-philosophies and strategies (Hargens, 2005). This new framework forms connection among body, mind and spirit in the areas of self, culture and nature. Furthermore, integral ecology incorporates four dimensions which are behavior, culture, experience and systems (Hargens, 2005).

Thus, integral ecology provides multidimensional thinking or systems thinking that refers to comprehensive understanding of individuals, cultures, behaviors and systems (Hargens, 2005). For instance, an integral ecologist contributes to recycling for several reasons: Recycling is important for the earth, for the humanity, for the nations and members of community and for themselves (Hargens, 2005). Seeing nature as a system (STS-2) is also linked to how individuals define human-nature relationship in a natural system (e.g., holistic or mechanistic view). Holistic view refers to describing nature as a living system, and mechanistic view is related to describing nature from human perspective (Capra, 1996; 2004).

Moreover, researcher adapted a number of STS from Assaraf and Orion (2005)'s systems thinking framework that was created in the context of hydro-cycle system. For instance, Assaraf and Orion (2005) stated that the ability to identify components of a system (e.g., hydro-cycle system) forms the characteristics of systems thinking. Researcher evaluated this characteristic in the context of sustainability and defined the third skill as identifying components of a system (STS-3).

The fourth skill has been determined as analyzing interconnections among the aspects of sustainability (STS-4). Nolet (2009) noted that systems thinking as a component of sustainability literacy not only incorporates relationships among species and nature, but also refers to relationships among ecological, economic and social systems. That is related to interrelationships among the social, economic and environmental aspects of sustainability (Nolet, 2009).

The fifth skill, recognizing hidden dimensions of a system (STS-5), has been adapted from Assaraf and Orion (2005)'s framework. The authors expressed that understanding hidden dimensions of a system is related to recognizing patterns and relationships that are not seen at first glance. For example, if there is a decrease in a kind of food production in a country, this case may be related to climate change conditions in another country. Some cases may be related to climate change even if it is not seen at first look.

Furthermore, UNECE (2011)'s ESD competencies framework, Sleurs (2008)'s competencies of ESD teachers framework, Sterling (2003)'s whole systems thinking paradigm and Sterling et al. (2005)'s linking thinking perspective were examined in this thesis. The sixth skill, the ability to recognize being part of the system (STS-6), has been identified as a systems thinking skill and competency for ESD educators (e.g., Sleurs, 2008; Sterling et al., 2005). That is to say, systems thinker is aware that she/he has a responsibility in the global problems or issues and takes responsibility of the choices they make (UNECE, 2011; Sleurs, 2008; Sterling, 2005).

The seventh skill, learning from the past experiences considering the relationships among past, present and future (STS-7), has been adapted from Assaraf and Orion (2005)'s framework and UNECE (2011). This skill suggests that future events may be result of the present interactions, and individuals should consider the present and past experiences by taking decisions for the future (UNECE, 2011; Assaraf & Orion, 2005).

The eight skill, understanding cycling nature of the system (STS-8), is related to recognizing cycling nature of the system. The meaning of this characteristic is to recognize that natural systems work in cycles (Assaraf & Orion, 2005). Earth support systems work in a cyclical basis such as recycling (Sterling, 2005). Ecological principles are related to cyclical processes and symbiotic networks. Furthermore, natural cycles (e.g. carbon, water, and nitrogen) are not separated. Instead, they are related to each other. Sustainability also requires thinking in circles (Litfin, 2012). Therefore, understanding cycling nature of the system is related to non-linear thinking as well (Kali, Orion & Eylon, 2003).

The ninth and tenth skills are related to empathy skills. Understanding other people's perspectives (developing empathy with other people-STS-9) is an important competency to be an ESD educator (Sleurs, 2008). Sterling et al. (2005) noted that individuals first should consider purpose and relationships in a system instead of blaming the components of the system (e.g., people). Systems thinking can promote individuals to build empathy with other people (Sleurs, 2008). Empathy is not only related to people, but also related to non-human beings (STS-10). It is reported that developing empathy with non-human beings and feeling connection to the world and to entire nature are important to understand interconnections in the world (Sleurs, 2008). Therefore, developing empathy with non-human beings has been defined as a systems thinking skill in this study.

The eleventh skill is related to developing sense of place (STS-11). Ardoin (2006) suggested that sense of place is related to describing a place as including multiple dimensions that are biophysical, political, psychological and socio-cultural. ESD incorporates these multiple dimensions of place, and therefore, sense of place could be evaluated in the holistic feature of ESD (Moseley et al., 2015). Sense of place promotes local and cultural sustainability (Sobel, 2004). Teachers can help students pay attention to the meanings we attribute to the places and how these places shape our beliefs, our identity, our roles in the place (Grunewald, 2003). It is assumed that a systems thinker could attribute multiple meanings to the places.

The last systems thinking skill has been determined as adapting systems thinking perspective to personal life (STS-12). STS-12 means that systems thinkers are able to investigate, especially, transformative actions for sustainability and integrate them into their personal life (Sleurs, 2008; UNECE, 2011).

These twelve STSs also constituted major themes and categories in order to guide data analysis. 13 themes and 36 categories have been determined for data analysis. Table 3.2 presents 12 STSs, major themes, categories and definitions. Detailed definitions of the categories are presented in the coding booklet (Appendix F).

In order to assess STS development of PSTs, researcher also developed a structured rubric. This rubric incorporated twelve STSs and a scale from zero to three (pre-aware, emerging, developing, mastery) was designed (Appendix E). Rubric has been tested and revised in the pilot study. In order to measure 12 STSs of PSTs, the researcher developed a series of qualitative measurement tools as presented in the following sections.

Table 3.2

General Systems Thinking Skills, Major Themes and Definitions

STS	Major Themes/Categories	Definitions
STS-1: The System Thinker identifies the meaning and key aspects of Sustainability	**Aspects of Sustainability** a.Identifiying all aspects of sustainability b.Identifiying two aspects of sustainability ability c. Identifiying one aspect of sustainability d. No aspect of sustainability	To be able to identify the meaning and key aspects of sustainability. These key aspects could be the relationship among environment, economy and society, thinking about the future, equity, diversity (biological, social, economic, cultural and religious), quality of life and justice (WCED, 1987; Mckeown, 2002).
STS-2: The System Thinker is able to see nature as a system	**Integral Ecology** a. Identifying more than two aspects of integral ecology b. Identifying two aspects of integral ecology c. Identifying one aspect of integral ecology d. No aspect **Human-Nature Relationship** a. Holistic view b. Mechanistic view c. No view	To be able to look at nature as a system considering the whole components. Seeing nature as a system (STS-2) is linked to multiple perspectives of integral ecology (Hargens, 2005) and also related to human-nature relationship (e.g., holistic or mechanistic view) (Capra, 1999).

Table 3.2 (Continued)

STS-3: The System Thinker is able to identify components of a system (Assaraf & Orion, 2005)	**Components of a system** a. Multiple Components b. Single Components c. No Component	To be able to identify components of a system according to context. The context may be a lake system, a forest system, a waste management system and also an economic or social system. System thinker can identify all the components of these systems.
STS-4: The System Thinker is able to analyze the interconnections among the aspects of sustainability by considering causes and consequences of the issues.	**Interconnection among the aspects of sustainability** a. Inter-connection among the all aspects of sustainability b. Interconnection among the two aspects of sustainability c. Separated explanation d. No interconnection	To be able to analyze interconnections among the aspects of sustainability. The meaning of this characteristic is to determine how the aspects of sustainability are related to each other in a system by considering the causes and consequences of the issues. That refers to interrelationships among the social, economic and environmental aspects of sustainability (Nolet, 2009).
STS-5: The System Thinker is able to recognize hidden dimensions in a system	**Hidden Dimensions in a system** a. Explaining the hidden dimension/s b. Not explaining the hidden dimensions	To be able to recognize patterns and interrelations that are not seen on the surface (Assaraf & Orion, 2010).
STS-6: The System Thinker is able to recognize that he/she is a part of this system and has a responsibility in the system.	**Recognizing own responsibility in the system** a. Stating own responsibilities b. Not stating the own responsibilities	To be able to realize a personal role in the global problems/issues and take responsibility of the choices they make (Sleurs, 2008; Sterling et al., 2005; UNECE, 2011).

Table 3.2 (Continued)

STS-7: The System Thinker is able to consider the relationship between past, present and future	**Making connections among past, present and future** a. Making connections among three time spans (past, present and future). b. Considering two time spans. c. Considering two time spans simply. d. Considering one time span.	To be able to take lessons from the past experiences and consider the results of these experiences for the future. Individuals can make connections between past, present and future actions (Assaraf & Orion, 2005; Sterling, 2005; UNECE, 2011).
STS-8: The System Thinker is able to recognize cycling nature of the system.	**Cycling nature of the system** a. Explaining cycling nature of the system. b. Not explaining cycling nature of the system.	To be able to recognize the natural systems work in cycles (Assaraf & Orion, 2005).
STS-9: The System Thinker develops empathy with other people	**Empathy with people** a. Considering other people's perspective in a complete way. b. Considering other people's perspectives in a simple way. c. Considering other people's perspective in one side. d. No empathy with other people.	To be able to view issues from other people's perspectives and understand their needs or reasons behind their actions (Sleurs, 2008; Tilbury & Cooke, 2005; UNECE, 2011).

Table 3.2 (Continued)

STS-10: The System Thinker is able to develop empathy with non-human beings.	**Empathy with non-human beings** a. Considering non-human beings. b. No empathy with non-human beings.	To be able to empathize with non-human beings. If someone cannot feel connection to the world, they cannot see the interconnections in the world (Sleurs, 2008). This interconnectedness is also related to beliefs, sense of awe, wonder, feelings, emotions, self-knowledge, relationships and creativity (Sleurs, 2008).
STS-11: The System Thinker is able to build sense of place.	**Sense of place** a. Multidimensional sense of place. b. Singe dimensional sense of place. c. No sense of place.	To be able to build sense of place. Sense of place refers to describing a place from complex, multidimensional perspectives and it is related to interconnected dimensions that are biophysical, psychological and socio-cultural (Moseley, Perrotta & Kharon, 2015). Sense of place promotes local and cultural sustainability (Sobel, 2004).
STS-12: The System Thinker is able to adapt systems thinking perspective to his/her daily life.	**Personal actions for sustainability** a. Transformative actions for sustainability. b. Simple actions for sustainability. c. No action.	To be able to take personal actions for sustainability. A person who has a system thinking perspective can investigate specific, transformative ways of action and integrate these actions to his/her life (Sleurs, 2008, UNECE, 2011).

3.3.2.2 Measuring Systems Thinking Skills

Several instruments were developed to measure STS: interviews, case study analysis, written samples and concept maps are the most used instruments employed by several authors (e.g., Assaraf & Orion, 2005; 2010; Brandstadter et al., 2012; Connel, et al., 2012, Zulauf, 2007). Assaraf and Orion (2005), for example, developed their own STS measurement tools in the earth systems education context. Within the context of the current thesis that considers twelve systems thinking skills, five qualitative STS measurement tools were developed and adapted. In addition, lesson plans were used as STS measurement tool in the context of the current thesis. Yet, the measurement tools developed for this thesis are not specific to measure one skill only, it is possible to measure more than one skill with one tool.

3.3.2.2.1 Essay Writing

In the literature, it is suggested that examination of written samples (e.g. essays) or case studies is one of the most practical assessment instruments of STS in higher education (e.g., Wang & Wang, 2011; Zulauf, 2007). Accordingly, essay writing was used in this thesis as one of the assessment instruments. The reason for using essay writing is to measure participants' skill that is "seeing nature as a system" (STS-2). In accordance with this purpose, participants were asked to write an essay to answer the question: "What does a tree mean to you?" which was originally used by Sterling et al. (2005). Sterling et al. (2005) noted that individuals usually see the distinctions rather than connections in a system. Therefore, he suggested that this question could be asked to individuals as a systems thinking exercise in order to reveal their way of thinking. Through this question, capturing participants' ontological descriptions of a tree was the aim. In this way, understanding how participants describe a natural system, whether they see complex relationships between human and nature or they see that human can control and manipulate nature, was targeted.

3.3.2.2.2 Case Study Analysis

One of the STS measurement tool used in this study is case study analysis. In the current study, the cases given to the participants are in the forms of a written case and videos. The written case used is titled as *Çorum Agricultural Land-Unfilled Emptiness,* and is related to the deterioration of agricultural lands by the companies for brick production (REC-Turkey, 2011). The videos used however, were titled as *we are losing our pastures in Turkey,* and *the most expensive meat is consumed in Turkey* due to deterioration of the ecosystems and agricultural lands because of the airport construction and revealing its social, economic and environmental consequences. (CNN Turk, 2014). Accordingly, in the case study analysis participants were asked one open-ended question (*What does this story mean to you? Please, write your thoughts, opinions and feelings)*. The answers of the participants were analyzed in terms of three STSs as how they identify or perceive the cases in accordance with the key aspects of sustainability (STS-1), how they identify the components of a system (STS-3) and how they analyze interactions among the components in terms of sustainability perspective (STS-4). Sample explanations related to cases are presented in Appendix B.

3.3.2.2.3 Semi-Structured Interviews

Interviewing is the basic method to gather in-depth and rich data and building interaction between respondent and interviewer (Fontana & Frey, 2005). There are different types of interviewing methods in qualitative research that are used based on the purpose of the research (Fontana & Frey, 2005). In this study, semi-structured interviews were employed in order to obtain deep information about participants' STS in the learning process. Semi-structured interviews consist of less structured and open ended questions (Merriam, 2009). Interview questions were prepared by the researcher based on the context of this study and each question was written to measure specific STS. Interview questions provided the researcher to measure twelve STSs determined in the previous stage. For the validity of the interview questions, researcher's supervisor examined the questions in accordance with the corresponding STS for each question. The questions and corresponding STS are presented in the (Appendix C).

3.2.2.2.4 Concept Maps

Concept maps are powerful tools to measure what individuals know and how they think (Tripto, Assaraf & Amit, 2013). Concept maps consist of concepts and relationships. The relationships represent the link between concept pairs in one word or sentence (Novak & Gowin, 1984 (as cited in Raved & Yarden, 2014). In addition to hierarchical concept maps, there are also cycling concept maps. Hierarchical concept maps are employed to structure hierarchical or static knowledge. On the other hand, cycling concept maps are used as an effective tool to structure functional or dynamic relationships between concepts (Safayani, Derbentseva & Canas, 2004). Systems thinking requires understanding cycling nature of the system (Assaraf & Orion, 2005). Accordingly, in the main study PSTs were asked to draw two concept maps in order to understand how they show the components, hidden dimensions and relationships of a system in consideration. In the pilot study, PSTs practiced drawing concept maps, and in the main study they drew two concept maps which were related to second and third modules of the course. The context of the concept maps of the main study were as follows: 1. Eymir Lake system 2. Sustainability solutions - working in backyard. Evaluation of the concept maps, however, was realized through the rubrics that were prepared by the researcher to measure three STSs (STS-3, STS-5 and STS-8).

3.2.2.2.5 Field Reports

Field reports prepared by the participants after each outdoor activity within the context of outdoor ESD course were also employed as one of the STS measurement tool. The structure of the field reports were prepared by the researcher for each activity and included four main sections as *learning objectives, background information*, *activity* and *discussion.* The validity of the reports as measurement tools was examined by the researcher's supervisor. During the implementation, participants were asked to fill the required fields in the reports. For the first activity, for example, participants were asked to observe woodland ecosystem (components and interactions) and write their observations, and they were asked to answer several questions such as *Think about what you have seen in Eymir this week?, What do you infer from your observations? Or you calculated how much carbon a tree stores in a day, so explain how to use this data to describe sustainability in Eymir.* Moreover, each field report was prepared to develop and measure specific STSs. The field reports and relevant targets along with the measured STSs are presented in the Table 3.3. Field report examples are presented in Appendix D.

Table 3.3

Field Reports as a Measurement Tool and Corresponding STS

	Field Reports	STS
Pilot Study	• Sustainable Use of a Lake	STS-1, STS-2, STS-3, STS-4, STS-5
	• Transforming Waste to Wealth	STS-6 and STS-8
Main Study	• Sustainable Use of a Lake (Ecosystem of Eymir Lake) • Sustainable Use of a lake (Water Quality Monitoring in Eymir Lake) • Sustainable Use of a Lake (Human Use in Eymir Lake)	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7 and STS-9
	• Sustainability Solutions (Working in Backyard)	STS-6 and STS-8

3.2.2.2.6 Lesson Plans

In the main study, PSTs were required to prepare an outdoor ESD lesson plan as a final assessment. The aim of the assignment was to reveal how PSTs could integrate their STS into an instructional planning. For this purpose, participants were supplied with an outline including some instructions about preparing outdoor ESD lesson plan and the grading procedure of the lesson plans (Appendix G). Initially, they were requested to choose a big idea from the elementary science education curricula. They were asked to prepare lesson plan in three parts as introduction (description of the objectives), teaching procedure (what kind of teaching procedures used) and assessment (how to measure targeted objectives). PSTs worked in groups of two people, and they were asked questions related to their lesson plans during the third interview (Appendix C).

All the measurement tools used in this study are listed in Table 3.4 with the corresponding STS and validities.

Table 3.4

STS Measurement Tools, Corresponding STS and Validity of the Tools

The Tool	Measured STS	Validity
1.Essay Writing	STS-2	• Developed by Sterling et al. (2005) and adapted by the researcher and reviewed by an ESD expert.
2.Case Study Analysis	STS-1, STS-3, STS-4	• 4 ESD experts evaluated the cases.
3.Semi-Structured Interviews	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-8, STS-9, STS-10, STS-11, STS-12	• Developed by the researcher according to STS and reviewed by the researcher supervisor.
4.Concept Maps	STS-3, STS-5, STS-8	• Developed by the researcher and reviewed by the researcher's supervisor.
5.Field Reports	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-8, STS-9	• Developed by the researcher and reviewed by the researcher's supervisor.
6.Lesson Plans	STS were explored in in the PSTs' explanations	• The outline for the lesson plans was developed by the researcher and reviewed by the researcher's supervisor

3.3.3 Stage 3: Outdoor ESD Course Development

The outdoor ESD course was developed by considering the results of gap analysis (general systems thinking skills resulted from gap analysis-Table 3.2). It was assumed that outdoor ESD course could develop STS of PSTs because outdoor education provides opportunities to integrate all elements of ESD by means of allowing participants direct experiences with the natural system as well as fostering sense of place (e.g., Higgins, 2009). Therefore, in line with the above reasoning planned ESD course to develop PSTs' STS is based on the outdoor activities.

Outdoor activities designed within the context of the ESD course comprised of two field trips titled as "Sustainable Use of a system (a Lake)" and "Transforming Waste to Wealth" and pilot implementation of the field trips were explained in the followings sections (section 3.3.4).

Field trip 1: Sustainable Use of a system (a Lake)

The first field trip was designed to help PSTs realize the cyclic structure of a lake system in terms of its social, economic and environmental features. Accordingly, the field trip was realized in three weeks through the following context: *Observation of surrounding forest ecosystem*, *Measurement of water quality parameters* and *Determination of human uses in the lake environment.*

Field trip 2: Transforming Waste to Wealth

The target of the second field trip was to help PSTs realize composting and gardening process as a sustainable and cycling system and help them make connections between natural cycles, human consumption patterns, composting and gardening process and realize individual responsibilities.

3.3.4 Stage 4: Pilot Study

Pilot study in a research refers to small scale version of the planned study or miniature version of the main study. Pilot studies are used to guide the development of the research plan (Prescott & Soeken, 1989 (as cited in Kim, 2011). Pilot studies help researchers make necessary adjustments and revisions in the main study (Kim, 2011). In qualitative research, pilot studies are used to train the researcher (Kilanowski, 2006) and improve the credibility of the qualitative research (Padgett, 2008). Through pilot studies, qualitative researchers can narrow or expand their research topic and can more clarify their research (Denzin & Lincoln, 1998). Therefore, pilot study in qualitative research plays a vital role (Kim, 2010). Accordingly, the pilot study of the current study was designed to reach three following targets: *to assess STS measurement tools developed by the researcher, to measure current systems thinking skills of PSTs, to develop and conduct a pilot version of the outdoor ESD course.*

3.3.4.1 Participants

Pilot study was conducted in an environmental science course during the 2013-2014 fall semester in the Department of Elementary Education in one of the well-known universities in Turkey. Twenty nine senior PSTs who were in their seventh semester of science teacher education program participated in the pilot study. Participants' age ranged from 21 to 25. Essay writing and case study analysis were conducted with 29 PSTs. Semi-structured interviews were conducted with volunteer participants. Six participants (3 female, 3 male) attended in the first interviews after the essay writing and case study analysis, and 5 participants (3 females, 2 males) participated in the second interviews.

3.3.4.2 Pilot Implementation of Outdoor Activities (Field Trips)

Field trips were implemented as a part of environmental science course with the attendance of 29 PSTs. The implementation of the Field Trip-1 *(Sustainable Use of a system (a lake)* was realized through a group work, and groups were given tasks according to the three phases of the trip. After the participants completed the tasks, they were asked to share their data with other groups and prepare field reports individually. Accordingly, five groups were set and each group worked on one phase: Two groups examined water quality while two groups observed forest ecosystem, and one group determined human uses.

Field Trip 2 (*Transforming Waste to Wealth)* was performed two weeks after the first trip. Before the field trip, 30-minute presentation about world food system, solid waste management and composting process was employed. After that, PSTs were informed about how to make compost in the backyard, and composting process was initiated together. PSTs were asked to observe and mix the compost and also measure the temperature of the compost for three weeks (until the end of the semester). Each PST observed the composting process and took field notes during for three weeks. Finally, they completed their field reports. Corresponding STS were intended to be measured in two field reports. They are presented in Table 3.5.

3.3.4.3 Data Collection

Data collection procedure in the pilot study was comprised of five tools developed for this study. Firstly, essay writing was conducted, and case study analysis was implemented. After that, semi-structured interviews were conducted in two stages: the first interviews included eight questions specifically related to essay writing and case study analysis, and the second interviews included 15 questions related to the context of field trips. Interviews were intended to measure 12 STSs. Furthermore, in the first interviews and in the field reports, PSTs were asked to draw concept maps related to the context. Through the field trips, PSTs completed the field reports and drew concept maps. The implementations schedule of the STS measurement tools are presented in the below Table 3.5.

Table 3.5

STS Measurement Tools Implementation Schedule for the Pilot Study

Measurement Tools	Descriptions	Time	Measured STS
1.Essay Writing	Context: What does a tree mean to you?	November 2014 (before the field trips)	STS-2
2.Case Study Analysis	Written case; Çorum Agricultural Land-Unfilled Emptiness. What does this story mean to you? Please, write your thoughts, opinions and feelings.	November 2014 (before the field trips)	STS-1, STS-3, STS-4
3. Semi-Structured Interviews	Interview-1 (related to essay writing and case study analysis)	November 2014 (before the field trips)	STS-1, STS-2, STS-3, STS-4, STS-5, STS-9
	Interview-2 (related to field trips)	January 2015 (after the field trips)	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-8, STS-9, STS-10, STS-11, STS-12
4. Field Reports	Two field reports completed after the field trips	November to December 2014	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-8, STS-9
5. Concept Maps	Concept maps drawn in field reports	November to December 2014	STS-3, STS-5, STS-8

3.3.4.4 Data Analysis - Rubric Development

Rubrics used in higher education include two objectives: *Determining a criteria for evaluation* and *determining an appropriate and relevant scoring system (*Peat, 2006). The rubric developed for this study to analyze essay writing, case study analysis, interviews and field reports was based on the 12 systems thinking skills that are presented in Table 3.2. The rubric, on the other hand, included four levels to rate PSTs' systems thinking skills development. These levels are mastery (3), developing (2), emerging (1) and pre-aware (0) (Appendix E). The validity of the rubrics was evaluated by three experts on ESD.

Moreover, a second rubric was developed for the evaluation of the concept maps and an expert on ESD examined the descriptions in the rubric. Concept map rubric was prepared based on measuring STS-3, STS-5 and STS-8 skills. Concept maps' evaluation criteria were determined in terms of mastery, developing and emerging levels. The concept map models were evaluated based on their complexity and three STS (STS-3, STS-5 and STS-8).

The characteristics of the rubrics are summarized in Figure 3.2. The rubrics for evaluating STS and concept maps are presented in Appendix E.

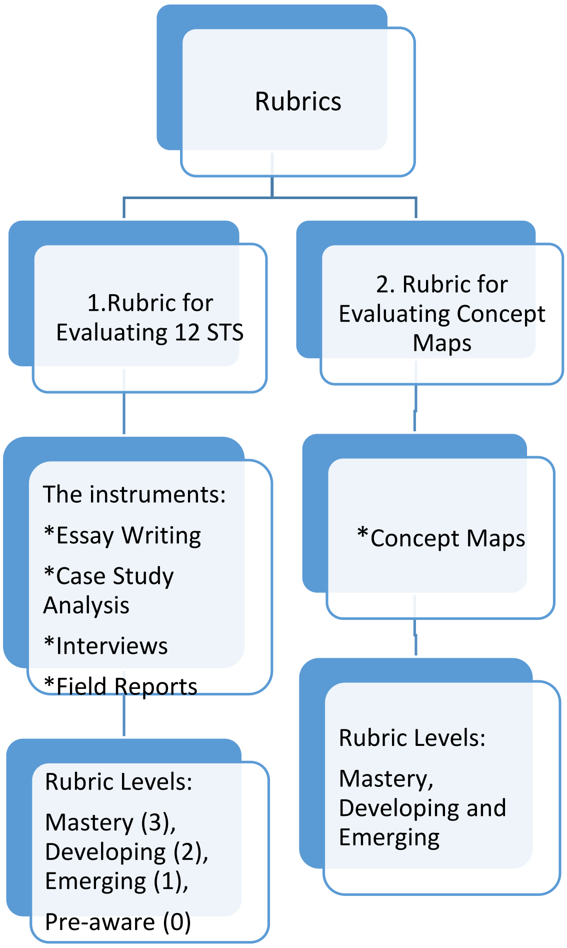

Figure 3.2 Rubrics for evaluating STS and concept maps

In order to provide reliability of the measurement tools, an independent coder (expert on ESD) analyzed all the interviews (the first and second one) and rated based on the rubric (Appendix E). Inter-rater reliability was 93% for the first interviews and 96% for the second interviews. Furthermore, 20% of 29 essays and 20% of 29 case study analyses were examined by the independent coder in order to provide reliability. Inter-rater reliability for the essay writing was found as 100% and inter-rater reliability for the case study analysis was 88%.

3.3.5 Stage 4: Main Study (Case Study)

The research question of the main study is *"How can PSTs' systems thinking skills be developed through the outdoor based ESD course?"* In accordance with the constructivist paradigm and systems perspective, qualitative case study was conducted to answer this research question.

Case studies provide understanding of a phenomenon in a holistic way considering different aspects in the real environment (Stake, 1995). Qualitative case studies include various definitions. According to Merriam (2009), qualitative case study is an inductive and mainly descriptive strategy including its boundaries or limits. Creswell (2007) suggests that case studies include a bounded system (one case) or multiple bounded systems (multiple cases) and extensive data sources to collect data. Furthermore, according to Yin (2009), qualitative case study represents an empirical inquiry that emphasizes a phenomenon in depth and in a real life context. If the aim of the researcher is to understand "Why?" or "How?" the program worked, he/she should conduct a case study (Yin, 2009). Qualitative case studies include a unit of analysis which is defined as a way of understanding what the case is. A case can be an individual or individuals or an event or a program (Yin, 2009). According to Yin (2009), qualitative case studies consist of four basic types of designs that are single or multiple and holistic or embedded case study designs. That is, qualitative case studies can be single case holistic or multiple case holistic designs and single case embedded or multiple case embedded designs. Single or multiple case studies are related to number of cases in the study and embedded or holistic case studies are related to number of unit of analysis in the study. Accordingly, the research design of this study is single case embedded design with embedded units within the context of Elementary Science Education (ESE) program at METU. Outdoor ESD course was designed as single case and participants' systems thinking skills through the course (based on three modules) were identified as a unit of analysis of the case. The boundary of this case study was determined according to time and place. It was bounded by data collection through one semester (12 weeks) and by PSTs in the elementary science education program. Figure 3.3 shows single case embedded design conducted for this study.

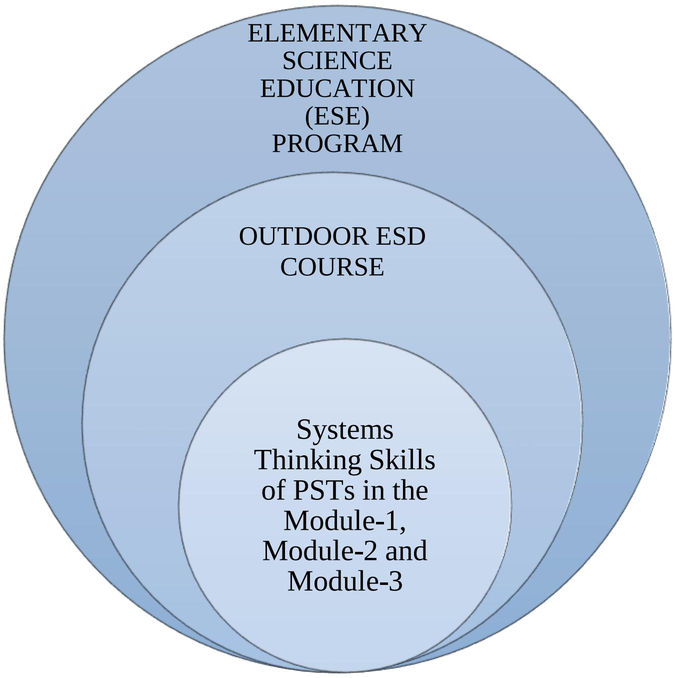

Figure 3.3. Single Case Embedded Design with Multiple Unit of Analysis

3.3.5.1 Participants

Main study was conducted within the context of the course titled "*Laboratory Applications in Environmental Education*" during the 2013-2014 spring semester in the Department of Elementary Science Education in one of the well-known universities in Turkey. Eleven PSTs attended in the course and data were collected from eight participants (3 males, 5 females) who volunteered to participate in the research and attended in all the lectures and field trips through the semester. All of the participants hold similar academic background. They all completed required science and environment courses. However, some participants have different personal background details. For instance, one of the participants has been working in an education center for children for one year and she has some field experiences related with science education and environmental education. Another participant grew up in a farm therefore he was more experienced about gardening practices. Figure 3.4 presents demographic characteristics of the participants.

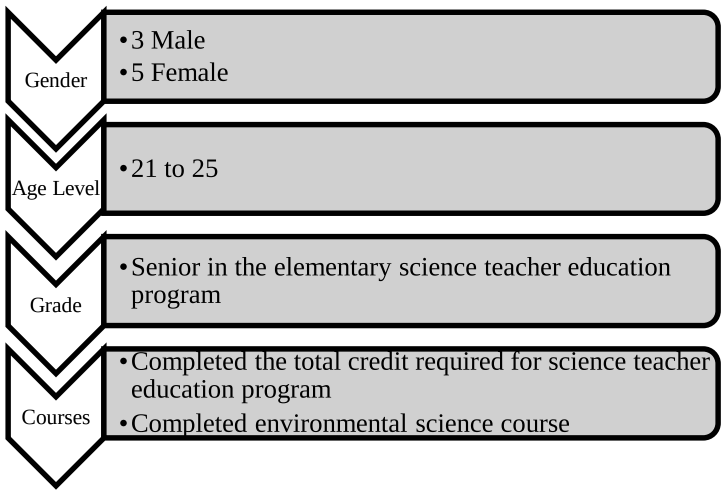

Figure 3.4 Demographic Characteristics of the Participants of the Main Study

3.3.5.2 Context of the Study: Outdoor based ESD Course

The course titled "*Laboratory Applications in Environmental Education*" was redesigned based on outdoor ESD context in order to foster STS of PSTs. The content of the course included field trips to Eymir Lake and composting activity. Content of the course has been revised for inclusion of the twelve systems thinking of this thesis. New activities (eg., measuring carbon emission of the trees and creating spiral garden) and new discussion questions have been added to the outdoor exercies. All the questions in the field reports have been modified so as to measure the system thinking skills. For example, in the first outdoor exercise which is related to ecosystem investigation in Eymir Lake, participants were asked a question related to current and future use and their inferences related to the future situation of Eymir. They were also asked to interpret the data (eg., calculation of carbon in the trees or water quality measurements) for describing sustainable use of Eymir. Thus, the discussion questions provided information about systems thinking skill development of participants. Moreover, concept maps have been integrated to course content as for the same reason. This outdoor ESD course was held in three hours each week and lasted eleven weeks. Outdoor based ESD course was designed through the results of the pilot study with the sustainable use of natural resources' point of view. Therefore, the course was designed and implemented through three Modules: *Determining Initial state of STS, Developing STS: What is Sustainable use of a system? And Developing STS: Sustainability solutions-Working in the backyard.* Six weeks of the course were held outdoors for the field trips and five weeks of the course were indoors (discussion weeks). At the end of the course, PSTs were asked to prepare a lesson plan with the big idea to foster elementary students' STS through an outdoor ESD course.

3.3.5.2.1 Procedure-Implementation of the Outdoor ESD Course

Outdoor ESD course has been implemented in three modules. The first module included systems thinking activities in order to determine initial state of the PSTs' systems thinking skills as explained in the following part.

MODULE I. Determining Initial State of STS

WEEK-1: Warming up - INDOOR

Date: 20.02.2014

Duration: 3 hours

In this week, PSTs were informed about the course content and syllabus. They were informed that this course was planned in terms of a holistic or systemic understanding. In addition, they were informed about the research hold in the course briefly, and they were asked whether they would like to be volunteer to participate in the research part of the course.

WEEK-2: Thinking Exercise- INDOOR

Date: 06.03.2014

Duration: 3 hours

Two of the data collection tools (essay writing and case study analysis) were implemented. PSTs were requested to write an essay answering the question: "*What do a tree and a lake mean to you?"* Case study analysis was carried through watching the video titled "*We are losing our pastures in Turkey*" which lasted 45 minutes. Afterwards, PSTs were asked to write their comments, opinions, feelings related to the case. After this lecture, the first interviews were conducted with volunteer PSTs.

MODULE-II. Developing STS: What is Sustainable Use of a System?

The main idea for constructing the Module II is to help PSTs understand complex systems in nature and the meaning of sustainable use of a natural system. Thus, the module includes field trips to Lake Eymir which is introduced to the participants as a natural system. The duration of Module II was five weeks (from week 3 to week 7) three of which were carried out outdoors.

WEEK-3: The need for systems thinking - INDOOR

Date: 13.03.2014

Duration: 3 hours

Objectives:

- To introduce the ways of thinking.

In the course, a presentation including the topics of mechanistic view of science, holistic science, the need for systems thinking and sustainability and gaia theory which were developed by James Lovelock in 1960 (Lovelock, 2000) was given. Moreover, PSTs were informed about the next week's content that will be held in Lake Eymir, and they were requested to be prepared for the field trip. Furthermore, PSTs were informed that the context of the first field trip report that was uploaded to the university's webinar system, and they were requested to read the report before coming for the field trip.

WEEK-4: Sustainable use of a Lake: Ecosystem of Eymir

OUTDOOR (Field Trip-1)

Date: 20.03.2014

Duration: 3 hours

Objectives:

- To explore the forest ecosystem of Eymir Lake
- To observe and feel the nature around the lake

Accordingly, the field trip was implemented in the forest area of Lake Eymir. Lake Eymir is a natural reserve area located at 20 km from the city center in the south of Ankara. It is a shallow lake with a length of 13 km and the deepest part of the lake is 5 m. The lake is located in a valley system, and it is surrounded by a forest area. Furthermore, Lake Eymir is a recreational area that includes several cafes and restaurants and visited by many people living in Ankara to relax, spend time in nature and do several outdoor activities. Moreover, the lake is located in the territory of the university, and thus it is administrated by the university (Figure 3.5). Before the field trip started, PSTs were informed about the history and current use of the lake. The task for the trip was, as defined in the field trip report, to examine the forest ecosystem of the lake. They were asked to observe the forest ecosystem, examine types of the trees, plants, and climate and calculate carbon storage of the trees (Figure 3.6). Participants studied in groups of two or three; however, they prepared individual field reports (Appendix D).

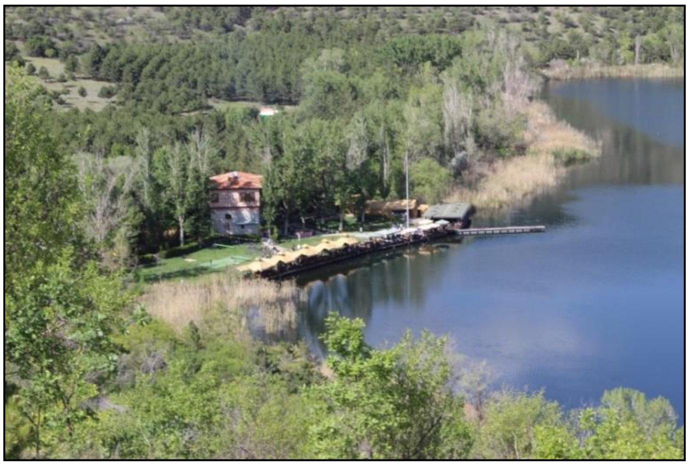

Figure 3.5 Lake Eymir

Figure 3.6 Field Trip- 1: Observation of the Forest Ecosystem in Lake Eymir

WEEK-5: Sustainable use of a Lake: Water Quality Monitoring in Eymir

OUTDOOR- (Field Trip-2)

Date: 27.03.2014

Duration: 3 Hours

Objectives:

- To explore water quality of Lake Eymir in line with the assigned parameters.
- To explore, referring to the past measurements, if there are any changes occurred in the concentrations of the measured parameters
- To evaluate possible reasons and results of the change in the concentrations.
- To discuss the future of the lake through making connections with the global environmental challenges (biodiversity loss, deforestation and climate change)

After PSTs examined the forest ecosystem of Eymir, in week 5, they were asked to monitor the water quality in the lake through the parameters assigned.

Before the field trip, researcher prepared the in-situ water quality measurement equipments (PH meter, DO meter, turbidity meter, sechi disk, D-net etc.). PSTs were given a short description related to the use of the water quality measurement equipments and they were asked to make in-situ measurements in the lake to represent its quality as far as the given parameters are concerned. Each group measured water quality parameters of the different sites of the lake and compiled the data to have a whole data set of water quality parameters of Lake Eymir (Figure 3.7). Individual field reports were prepared by the students to reflect their evaluations on the results (Appendix D).

Figure 3.7 Field Trip 2: Water Quality Monitoring in Eymir Lake

WEEK-6: Sustainable use of a Lake: Human Use in Eymir

OUTDOOR-(Field Trip-3)

Date: 03.04.2014

Duration: 3 hours

The purpose of the third field trip to Lake Eymir was to investigate human use in Eymir Lake. Accordingly, the objectives for the trip were set as:

- To explore how people use Eymir Lake.
- To analyze the possible impacts of human use in Eymir in terms of sustainability.
- To discuss Eymir as a system by considering the results of three field trips together.

PSTs were asked to explore human impact in Lake Eymir. With this field trip, it was aimed to help PSTs to be aware that Lake Eymir does not only have environmental value, but it has also economic and social value, so it was also aimed to help them make evaluations through sustainable use of the lake. In view of that, they were given freedom to design their research. As a result, some conducted interviews with visitors, and some of them conducted interviews with cafe and restaurant owners and observed how they dump their wastes, how they conserve the lake, etc.

WEEK-7: Discussion: Systems Thinking Exercise through the Findings of Module-II-INDOOR

Date: 10.04.2014

Duration: 3 hours

Objectives:

- To discuss Eymir as a system through sustainability perspective.

After three field trips to Lake Eymir, a discussion was held in the classroom within the context of the field reports, and PSTs were requested to draw a concept map related to human-nature relationship in Lake Eymir considering the results of the trips. The objective for the Week 7 therefore, was set as to discuss Eymir as a system through sustainability perspective and the discussion was constructed on systems thinking perspective. After the completion of Eymir field trips, the second interviews were conducted with the volunteer participants before the next lecture started.

MODULE- III. Sustainability Solutions

Module-III included activities related to sustainability solutions. This module that lasted four weeks aimed to encourage PSTs to explore solutions for sustainability in the context of composting and gardening and recognize personal responsibility in the system and cycling nature of the system.

WEEK-8: Sustainability Solutions-Working in the backyard

OUTDOOR (Field Trip-4)

Date: 24.04.2014

Duration: 3 hours

WEEK-9: Sustainability Solutions-Working in the backyard

OUTDOOR (Field Trip-5)

Date: 08.05.2014

Duration: 3 hours

The two weeks long outdoor exercises were compiled of gardening and composting activities. The objectives set for eighth and ninth weeks were;

- To help students make connections between natural cycles and composting process.
- To introduce composting process as a part of the sustainable system.
- To help students explore how compost can be transformed to food.
- To acquire interest to work outside, planting, composting.
- To compare human system and natural systems through composting and gardening process.
- To be aware of the individual responsibilities.

Before PSTs participated in several outdoor activities like composting, watering, planting, a short presentation about composting, sustainable food consumption and sustainable agriculture was given by the researcher. Within the context of this module, the soil was prepared for planting in the backyard of the faculty. The compost made in the previous semester during the environmental science course was used to improve the soil. Thus, PSTs had a chance to see how wastes could be transformed to a healthy soil through composting. After preparing the soil, PSTs collected the organic wastes from the canteen, and they brought wastes from their houses to initiate a new compost pile. By creating the compost pile, they learnt how natural cycles (carbon, water and nitrogen cycles) are related to composting process. Throughout two weeks, a new compost pile was initiated. Then, a drip water irrigation system was constructed and seedlings were planted. The researcher made an effort to use recycling materials in the course and contact with the community to get their help such as canteen workers, other colleagues in the faculty and forestation institution at the university. Thus, PSTs could see how a sustainable system could be created in the backyard of the faculty together. Moreover, they became a part of all these processes and learnt to make cooperation with all the stakeholders. They observed all the processes in the garden and completed their field report based on their observations and reflections (Figure 3.8).

Figure 3.8 Field Trip 4: Working at the backyard Gardening and Composting

WEEK-10: Discussion-Systems Thinking Exercise through the Findings of Module III-INDOOR

Date: 15.05.2014

Duration: 3 hours

This was a discussion week during which the outdoor experience was discussed as a whole through the context of the filed reports. At the end of the lecture, PSTs watched a video titled *“The most expensive meat is consumed in Turkey”* (CNN Turk, 2014). Afterwards, they were asked to write an evaluation on the case they watched on the video. (Case Study-II).

WEEK-11: Completing the Circle - Sustainable Use and Sustainability Solutions-OUTDOOR):

Date: 22.05.2014

Duration: 3 hours

At the end of the course, Lake Eymir was visited again in order to complete the circle of the course. PSTs expressed their critics and reflections about the whole course. At the end of the semester, the third interviews and second concept maps were conducted, and PSTs completed their lesson plans. In Figure 3.7 the structure of the outdoor ESD course is summarized.

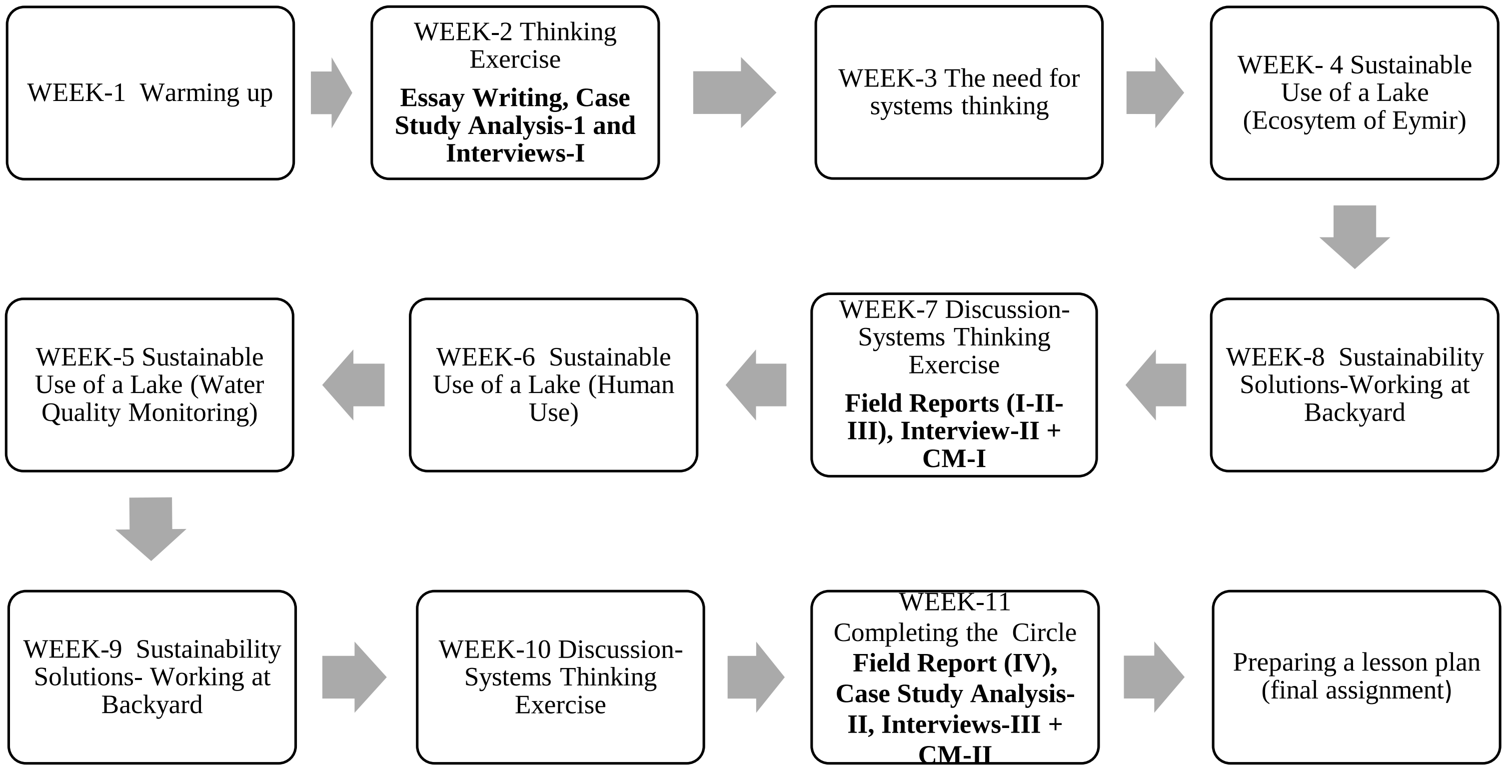

Figure 3.9 Outdoor ESD Course: The content

3.3.5.3 Data Collection

Data collection procedure in the main study was comprised of the implementation of the five tools developed for this study. Firstly, essay writing was conducted, and after the essay writing, case study analysis was implemented. After that, semi-structured interviews were conducted in three stages: The first interviews included 13 questions, specifically related to essay writing, case study analysis and Lake Eymir. Second interviews included 12 questions related to the context of field trips to Lake Eymir, and the third interviews included three parts which were related to sustainability solutions-working in the backyard, lesson plans prepared at the end of the course and development in STS through the course. Interview questions and corresponding STS can be seen in the Appendix C. Through the field trips, PSTs completed the field reports and drew concept maps. The implementations schedule of the STS measurement tools in the main study are presented in the below Table 3.5.

Table 3.6

Data Collection Scheme in the Main Study

Time	The Tool	Description	Measured STS
	Essay Writing	Context: "What does a tree and a lake mean to you?"	STS-2
February 20- March 6 2014	Case Study Analysis-I	Case-1: We are losing our pastures in Turkey The question asked: "What does this story tell you? Please, write your thoughts, opinions and feelings"	STS-1, STS-3, STS-4
	Interview-I	13 questions (related to essay, case study and Eymir Lake), Lasted 30 minutes	STS-1, STS-2, STS-3 STS-4, STS-5, STS-6 STS-7, STS-9
March 13- April 10 2014	Field Reports (I-II-III)	Field reports related to Module-II	STS-1, STS-2, STS-3 STS-4, STS-5, STS-6 STS-7, STS-9
	Interview-II + CM-I	12 questions (related to Module-II Lasted 40 minutes	STS-1, STS-2, STS-3 STS-4, STS-5, STS-6 STS-7, STS-8, STS-9 STS-10, STS-11, STS-12
		Concept map-II	STS-3, STS-5, STS-8
	Field Report (IV)	Field reports related to Module-III	STS-6, STS-8
April 24- June 6 2014	Case Study Analysis-II	Case-2: The most expensive meat is consumed in Turkey The question asked: "What does this story mean to you? Please, write your thoughts, opinions and feelings".	STS-1, STS-3, STS-4
	Interview-III + CM-II	1. Questions related to case study and concept map 2. Questions related to lesson plans 3. Questions related to development of STS (lasted 60 min)	STS-1,STS-3, STS-4 STS-5, STS-6, STS-7 STS-8, STS-9, STS-10 STS-11, STS-12
	Lesson Plans	Five lesson plans were prepared at the end of the semester	STS were explored in the PSTs' explanations

3.3.5.4 Data Analysis

This study is a single case embedded design with multiple unit of analysis. According to Merriam (2009), in a case study all the data about the case should be brought and organized together. In this study, systems thinking skills of participants were measured by the tools and were developed through the three modules of outdoor ESD course. The data were analyzed through qualitative way. Constant comparative method developed by Glaser and Strauss (1967) were employed to analyze qualitative data. According to Glaser and Strauss (1967) in the constant-comparative method " the analyst starts by coding each incident in his data into many categories of analysis as much as possible, as categories emerge or as the data emerge that fit to an existing category" (p.105). Furthermore, according to Merriam (2009), "constant comparative method involves comparing one segment of data with another to determine similarities and differences". In this study, themes and categories have been created through both inductive and deductive ways. First, a list of codes (pre-code list) was prepared based on the general systems thinking framework and rubric. Later, the codes evolved from the data have been added to the pre-code list. Ultimately, a coding booklet (Appendix F) has been prepared. Definition of the codes has been written because it could be useful for other researchers who may think about the same phenomena while coding a similar data (Miles and Huberman, 1994). Afterwards, initial STS levels of participants have been determined based on the rubric including four levels which are mastery, developing, emerging and pre-aware. Mastery level refers to the highest level for STS development while pre-aware level refers to the lowest level for STS development (Appendix E). Detailed qualitative data analysis descriptions of the tools are presented in the following sections.

3.3.5.4.1 Data Analysis: Essay Writings

Essay writing has been used to measure the skill defined as "seeing nature as a system (STS-2)". Participants' essays related to the questions about *"What does a tree mean to you?* And *"What does a lake mean to you?"* were analyzed based on the two themes and four categories (Table 3.7). STS levels of the participants were evaluated based on the rubric (Appendix E).

Theme-1: Integral ecology

Integral ecology theme used in the data analysis has four dimensions (experience, cultural, behavior and systems) that represent the multiple perspectives of integral ecology. ***Experience*** refers to subjective experiences such as social, emotional, spiritual (e.g., personal experiences about a mountain). ***Cultural*** refers to morals, symbols, system, meaning, affect etc. (e.g., how human culture symbolize natural world). ***Behavioral*** is related to more technical issues such as physical boundaries, movements or measurements (e.g., measurement of the PH in a river, the height of a tree). ***Systems*** is related to interactions in the natural world (e.g., food chain, migration etc.) and human effect in the world (Hargens, 2005). Thus, analysis of essay writings was realized based on the four dimensions of integral ecology explained above together with rubric levels and divided into four categories (Table 3.7).

Theme-2: *Human-Nature Relationship*

The second theme, for analyzing STS-2 was determined as human-nature relationship. Two views for human-nature relationship, as suggested by Capra, (1991) were used to determine PSTs' views of human-nature relationship:

1. Mechanistic view: Describing natural system in terms of human perspective as humankind is separated from nature and rules nature.

2. Holistic view: Humankind is related to nature and natural systems are seen as a living system. Thus, mechanistic and holistic view constituted the categories related to human-nature relationship theme (Table 3.7).

Based on the themes and categories, the instances that were elicited in PSTs' responses in essay writing were determined and evaluated according to the STS levels. Besides, an independent coder (expert in ESD) analyzed two essay writings which were randomly selected.

Table 3.7

Themes and Categories in the Essay Writing Analysis

STS	THEME	CATEGORY
STS-2: Seeing Nature as a System	1.Integral Ecology	a. Identifying more than two aspects of integral ecology. (e.g., cultural, behavioral and experience)
		b. Identifying two aspects of integral ecology (e.g., cultural and behavioral)
		c. Identifying one aspect of integral ecology (e.g., cultural)
		d. No aspect (no particular aspect of integral ecology
	2. Human-Nature Relationship	a. Mechanistic View
		b. Holistic View
		c. No View

Participants' responses on their thoughts, opinions and feelings related to the given case were analyzed based on the three systems thinking skills: STS-1 (identifying aspects of sustainability), STS-3 (identifying components of a system) and STS-4 (analyzing interconnections among the aspects of sustainability). The themes for

analyzing STS were set in line with the rubric as "*Identifying aspects of sustainability" for* STS-1, "*Components of a system*" for STS-3 and *"Analyzing Interconnections among the aspects of sustainability* "for STS-4 (Table 3.8). The first theme included four categories and was evaluated in relation to using social, environmental and economic aspects of sustainability. The second theme referred to components derived from the case and included three
categories. Researcher determined possible components related to case before the data analysis and looked for how PSTs mentioned these components in the case study analysis. For example, for the first case study titled as "We are losing our pastures", researcher determined a number of components which could be nature, ecosystem, villagers, city life, construction, transportation, climate change etc. and searched for these components during the data analysis. The last theme also included four categories in relation to analyzing the interconnections among the social, economic and environmental aspects of sustainability (Table 3.8).

Besides, an independent coder (expert in ESD) analyzed two participants' case study analyses which were randomly selected.

Table 3.8

Theme and Categories set in the Case Study Analysis

STS	**THEME**	**CATEGORY**
STS-1: Identifying aspects of sustainability	Identifiying aspects of Sustainability	a. Identifiying all aspects of sustainability (e.g., Social, economic, environmental) b. Identifiying two aspects of sustainability (e.g., Social and environmental) c. Identifiying one aspect of sustainability (e.g., environmental) d. No aspect of sustainability (not including a particular aspect)
STS-3 Identifying components of a system	Components of a system	a. Multiple Components b. Single Components c. No Components
STS-4 Analyzing interconnections among the aspects sustainability	Interconnection among the aspects of sustainability	a. Interconnection among the all aspects of sustainability b. Interconnection among the two aspects of sustainability c. Separated explanation d. No Interconnection

3.3.5.4.2 Data Analysis: Interviews

While analyzing interviews first, each transcript was read and examined several times to make sense of data. Later, the unit of data which represents potential answers to the questions asked during the interviews were identified. Throughout the analysis, the themes and categories determined beforehand were explored. Data analysis continued to compare one unit of data with the other data (Merriam, 2009). The themes and categories for each STS were identified based on the general systems thinking skills (Table 3.2) and rubric. The themes and categories used for STS-1, STS-2, STS-3 and STS-4 were the same as the ones mentioned in the above section. Therefore, Table 3.9 presents the themes and categories for other skills (STS-5, STS-6, STS-7, STS-8, STS-9, STS-10, STS-11 and STS-12).

Table 3.9

Themes and Categories set in the Interviews

STS	THEME	CATEGORY
STS-5: Recognizing hidden dimensions	Hidden Dimensions in a system	a. Explaining the hidden dimensions. b. Not explaining any hidden dimension.
STS-6 Recognizing own responsibility in the system.	Recognizing own responsibility	a. Stating own responsibility b. Not stating own responsibility.
STS-7: Considering the relationship among past, present and future.	Making connections among past, present and future.	a. Making connections among three time spans (past, present and future. b. Making connections among two time spans (e.g., past-future). c. Considering one time span (e.g., present) d. No connections with time spans.
STS-8 Recognizing cyclic nature of the system.	Cyclic nature of the system	a. Explaining cycling nature of the system b. Not explaining cycling nature of the system
STS-9: Developing empathy with other people.	Empathy with people	a. Considering other people's perspective in a complete way b. Considering other people' perspectives in a simple way c. Considering other people's perspective in one side d. No empathy
STS-10: Developing empathy with non-human beings.	Empathy with non-human beings	a. Considering non-human beings b. No empathy with non-human beings
STS-11: Developing sense of place.	Sense of place	a. Multidimensional sense of place b. Singe dimensional sense of place c. No sense of place
STS-12 Adapting systems thinking perspective to personal life	Personal actions for sustainability	a. Transformative actions for sustainability b. Simple actions for sustainability c. No action

3.3.5.4.3 Data Analysis: Concept Maps

Concept maps were evaluated based on their complexity and non-hierarchical structure. Concept map analysis structure was based on the themes as number of components of the system, the number of connections (a measure of interrelationships), hidden dimensions and a measure of complexity. Moreover, a rubric for evaluating concept maps has been used. Concept map rubric included categories which were mastery, developing and emerging (Appendix E).

Furthermore, concept maps enabled researcher to examine the following systems thinking skills: STS-3 (identifying components of a system), STS-5 (recognizing hidden dimensions) and STS-8 (recognizing cyclic nature of the system) in a holistic way.

3.3.5.4.4 Data Analysis: Field Reports

Field reports were analyzed in a similar way as mentioned in section 3.3.4.4. Each participant's report was read several times, and participants' answers to the questions in the reports were analyzed based on the pre-determined themes and categories set for 12 STS.

3.3.5.4.5 Data Analysis: Lesson Plans

Lesson plans were analyzed to answer the question of to what extent participants could reflect STS in their instructional planning. Lesson plans were evaluated according to the lesson plan analysis rubric. In the first step of lesson plan analysis, the three parts of the plans (objectives, teaching procedure and assessment) were examined in order to reveal how PSTs integrated STS to lesson plans. Later, these parts were evaluated based on the three rubric levels (exemplary, making progress and needs development) as given in the rubric (Appendix E).

3.3.5.5 Trustworthiness of the Study

Trustworthiness is used as a term that refer to reliability and validity of qualitative studies (Lincoln & Guba, 1985). Trustworthiness is related to how the researcher could persuade readers that findings of the study are worth paying attention to (Lincoln & Guba, 1985). Several strategies are used in order to enhance trustworthiness of qualitative studies. These strategies are called “reliability”, “internal validity” and “external validity” (Merriam, 2009, p.213), or they are called by Lincoln and Cuba (1985, p.298) as “credibility”, “dependability” and “transferability” and “confirmability”. In this study, appropriate strategies were used to deal with reliability and validity concerns of the study.

3.3.5.5.1 Reliability (Dependability)

Reliability in qualitative research is related to finding consistent results with the data collected (Merriam, 2009). There are several ways to enhance reliability in qualitative studies. These are checking the transcripts, comparing data with the codes to be sure that there is not any mistake in the coding system and inter-coder agreement (Creswell, 2014). In this study, all the qualitative data were recorded and transcribed, and the transcripts were checked to ensure that there is not any mistake. Furthermore, all the transcripts were read and rated according to the coding booklet and rubric. Coding and rating process were repeated for several times to be sure that appropriate rubric levels were employed. Lastly, interrater reliability was provided to establish reliability of the rubric.

3.3.5.5.2 Interrater Reliability

Interrater reliability defined by Lecompte and Goetz (1982) means that multiple observers or coders reach the same conclusion about the phenomena which is evaluated. That is to say, interrater reliability refers to the agreement between different coders, and this agreement is calculated with a simple statistics which is the percentage (or proportion) of the agreements as shown= $\frac{\mathrm{Na}}{\mathrm{Na+Nd}}$ where $Na = the\ number\ of\ agreements,\ \ Nd = number\ of\ disagreements$ (Tinsley & Brown, 2000).

For example, if there is no disagreement between two coders or raters, reliability coefficient will be 1/1 which means that there is 100 % agreement between the coders. In this study, in order to provide interrater reliability, several ways were employed. One is that researcher should describe rubric criteria and grades carefully (Stellmack, Konheim-Kalkstein, Manor, Massey & Schmitz (2009). In this study, rubric criteria were determined carefully based on general systems thinking skills (Table 3.2) and revised several times by reaching to final decision for each item in the rubric. Another way is training the graders about the rubric (Zimmaro, 2004). For interrater reliability, primary researcher and an expert who is very experienced in ESD held several meetings, and researcher summarized her study and explained the coding procedure and structure of the rubric. Researcher and expert coded and graded a sample data together to understand how to decide category levels in the rubric. Miles and Huberman (1994) suggested that at least two coders should code 5-10 pages of the transcribed data separately and check the consistencies. Moreover, the authors suggested that agreement which is more than 70% could be acceptable; however, at the end, inter-rater agreement should be at least 90%.

In this study, the expert analyzed randomly selected data which are three essays (among 8), three case study analyses (among 16), a total of six interviews (among 24), nine concept maps (among 16), four field reports (among 32) and two lesson plans (among 5).

For the essays, expert analyzed data individually, and 67 % agreement was obtained. Researcher and expert discussed the disagreements and reached full agreements (100%). For the case study analysis, firstly, expert analyzed the data and inter-rater reliability was found below 90%. The Researcher and the expert discussed the disagreements, and the second interrater reliability was found as 94%. For the interviews, firstly inter-rater reliability was found as below 90%. After the discussion between the researcher and expert, the second inter-rater reliability was found as 95%. For the reliability of the field reports, initially, interrater agreement was found as 78%. After the discussions between the researcher and expert, the second inter-rater reliability was found as 89%. For the reliability of the concept map analysis, inter-rater reliability was found as 89%. Moreover, in terms of reliability of the lesson plans, firstly, inter-rater reliability was revealed as 83% and after the discussions between researcher and expert, inter-rater reliability was revealed as 100%.

Furthermore, in order to provide significance of interrater reliability Cohen (1960)'s kappa statistics (or kappa coefficient) was used. Kappa statistics reveals quantitative measure of the magnitude of agreement between coders (Viera & Garrett, 2005). Kappa value represents the difference between the observed agreement and expected agreement, and the value ranges from -1 to 1 scale. 1 shows perfect agreement. 0 is related to the agreement expected by chance and negative values refer to agreement less than chance. Table 3.10 shows the interpretation scale of kappa value.

Table 3.10

Interpretation of Kappa Value Source: Viera & Garret, 2005

	Poor	Slight	Fair	Moderate	Substantial	Almost perfect
Kappa	0.0	20	.40	.60	.80	1.0

Kappa	**Agreement**
<0	Less than chance agreement
0.01-0.20	Slight agreement
0.21-0.40	Fair agreement
0.41-0.60	Moderate agreement
0.61-0.80	Substantial agreement
0.81-0.99	Almost perfect agreement

According to results of interrater analysis of case study analysis, Kappa value was found 0.63, $p<0.001$ that is statistically significant, and it shows substantial agreement (Table 3.12). For the interrater analysis of interviews, Kappa value was found as .83, $p<0.001$. This measure of agreement is statistically significant, and it is considered as almost perfect agreement. Moreover, for the interrater analysis of the field reports, Kappa value was found as .83, $p<0.001$ which is statistically significant and shows almost perfect agreement. Interrater reliability analysis using Kappa statistics showed that there was a consistency between the researcher and expert for the rubric, and the results were satisfactory to indicate that scoring in the rubric is valid and reliable.

3.3.5.5.3 Validity

Validity in qualitative research refers to accuracy of the findings (Creswell, 2007). In this study, internal validity (credibility) and external validity (transferability) were provided with several strategies.

3.3.5.5.3.1 Internal Validity (Credibility)

According to Merriam (2009, p.213), internal validity or credibility in qualitative research deals with the question of "How congruent are the findings of the study?" To put it differently, internal validity is related to whether or not the researcher is really measuring what he/she thinks.

In this study, several strategies were used in order to provide credibility of the study. One is prolonged engagement and persistent observation (Creswell, 2007, p.207). In order to ensure validity of the findings, the researcher spent time in the field, and data were collected in three months until the end of the semester. This provided the researcher to build the feeling trust with the participants. Another strategy for ensuring accuracy of the findings is triangulation. To strengthen confidence in the findings, Patton (2002, p.556) suggested four kinds of triangulation strategies which are "methods triangulation", "triangulation of sources", "analyst triangulation" and "theory/perspective triangulation". In this study, data were obtained from multiple sources including essays, case study analysis, interviews, field reports and concept maps, and the researcher compared findings collected from different data sources.

Another common strategy to ensure internal validity is "peer review" or "peer examination" (Merriam, 2009, p.220). Peer review includes asking a peer or colleague to examine some parts of the raw data and evaluate whether interpretations are appropriate in relation to data. For the preparation of general systems thinking skills and data collection sources, the researcher and two experts in ESD talked and discussed several times. Furthermore, in the data analysis process one expert in ESD examined some parts of the data and discussed findings and interpretations. Moreover, researcher position or reflexivity is the strategy which allows the reader to understand how researcher approaches to the study and interprets the data (Merriam, 2009). In the previous section (3.2), researcher's position for this study was explained in detail. Furthermore, Shenton (2004) suggested tactics to help ensure honesty in informants as another strategy for providing credibility. This study was conducted with volunteer participants. They were informed that there was not right or wrong answer to the questions that they answered during the data collection process. In this way, participants felt comfortable while answering the questions and an honest and trustworthy environment was built in the course.

3.3.5.5.3.2 External Validity (Transferability)

External validity deals with "whether the extent to which the findings of a study can be applied to in other situations" (Merriam, 2009, p. 223). In other words, it focuses on whether the findings are transferable to other contexts and how findings can be generalized (Lincon & Guba, 1985; Miles & Huberman, 1994). In order to provide transferability of the study to other contexts, researcher should provide a thick description of the study. Since this study is a single embedded case design with multiple unit of analysis, researcher explained the cases, data collection tools and the research process in detail so that the readers can apply findings to their own particular settings.

3.3.5.5.4 Confirmability

Confirmability is related to whether the findings reflect the experiences and ideas of the participants rather than researcher's preferences and characteristics (Shenton, 2004). According to Shenton (2004) triangulation is one of the ways to reduce researcher's bias in the study. In this study, data were obtained from multiple data collection sources for triangulation. Moreover, the researcher should be aware of her or his predispositions during the study (Miles & Huberman, 1994). The researcher explained her background and position in this study in the section 3.3. Researcher was also self-aware of all possible biases in the study. Moreover, researcher described all the research process in detail and employed peer review to ensure that findings were not biased.

3.3.5.5.5 Ethical Issues

Miles and Huberman (1994, p.290) suggest that there are several issues that need to be considered before, during and after the qualitative studies. There are three critical ethical issues that need attention during the study which are "informed consent", "privacy, confidentiality and anonymity" and "avoidance of harm" (Miles & Huberman, 1994). Firstly, before the study started, necessary permission was obtained from the ethical committee in the university in order to conduct this study. At the beginning of the course, PSTs were given a syllabus of the course, and course content was explained in detail. Furthermore, they were informed that this course was a part of the study, and they learnt that they would participate in the research aspect of the course. However, participants were informed that they had an option not to participate in the research part of the study. Moreover, for the privacy of the study it was ensured that nobody could access the data. Participants' names were not used in the study for the anonymity, and they were given pseudo names. Moreover, there is not any harm or risk to participants in this study. As this course was usually implemented outside, necessary security issues were considered in order to prevent any harm or risk to participants.

3.3.5.5.6 Limitations of the Study

There are several limitations that need to be considered so that findings of this study could be interpreted based on these limitations. This study was employed in an outdoor based ESD course which was an elective course for pre-service science teachers, and the study was limited to this course's context. Therefore, this study could not be generalized to other contexts. Moreover, this study was conducted with only eight participants due to the nature of qualitative case study. For this reason, this study is limited to data obtained from eight participants' essay writings, case studies, interviews, concept maps and field reports. Hence, the study could not be generalized to larger samples. Moreover, this study is not an ethnographic or longitudinal study therefore, it could not be claimed that participants' life has changed through the study. A follow-up study could be conducted in order to reveal the reflections of systems thinking in participants' social and professional life.

Another limitation could be related to time constraints. This study was employed in one semester course. However, in order to reveal STS development process of the participants in the long term, the course could be implemented for a longer time. The next section presents the results of the study.

Researcher's bias could be considered as another risk that this study carries. As researcher of this thesis has many experiences related to outdoor education, ESD and holds her own perspectives, dispositions and beliefs. Therefore, in order to reduce researcher bias in a study reflexivity has been suggested. Johnson (1997) pointed out that through reflexivity researcher describes his/her self reflection related with potential biases and predispositions. Thus, researcher becomes self-aware of potential biases and try to control them in the study (Johnson, 1997). The researcher accepts that her personal view, her background and her experiences could have an effect on her role in this thesis. Therefore, she described her background in the researcher position part and at the end of the discussion section. Besides, she got feedbacks from her supervisor and her colleaugues to prevent any possible bias and increase validity of the study.

CHAPTER 4

RESULTS

This chapter brings the results of three phases of the thesis together; thus, it is comprised of three major parts as: the results of gap analysis, the pilot study and the main study. This chapter also highlights how PSTs reflect their systems thinking skills to instructional planning under the light of the outdoor ESD course they participated in. Accordingly, the flow chart for the results of the thesis is presented in Figure 4.1.

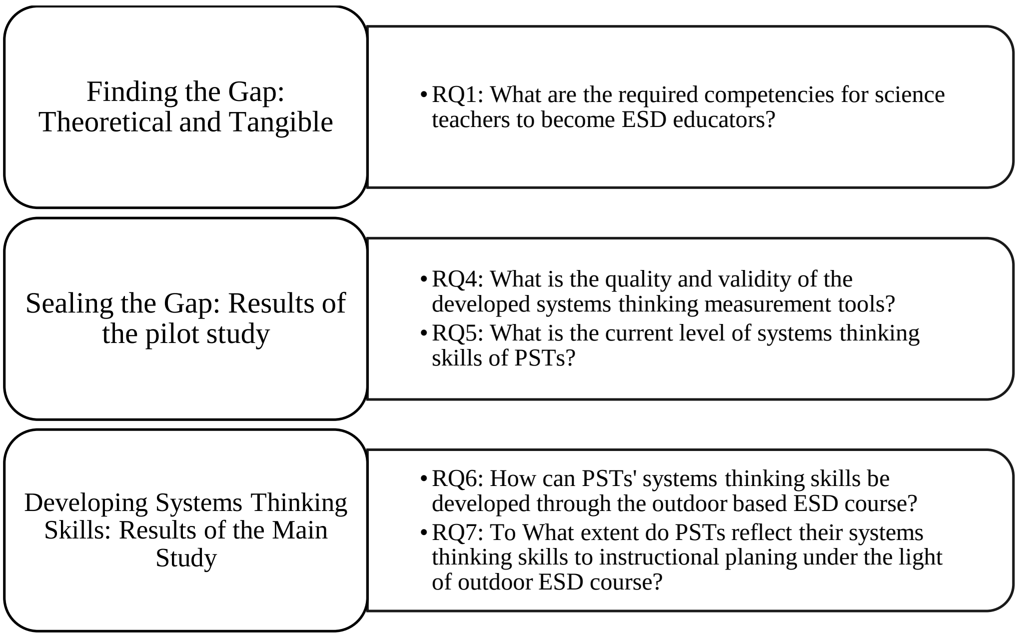

Figure 4.1. Flow of the Results

4.1 Finding the Gap

4.1.1 Theoretical Part

Theoretical part for the Gap Analysis is presented under two headings as *Determining the need: Competencies for Science Teachers and ESD educators* and *Detecting the gap: Current competencies of science teachers versus required competencies of ESD educators*.

4.1.1.1 Determining the Need: Competencies for STs, EE, ESD Educators

The competencies of STs were determined through three main documents. The first is the one that belongs to National Science Teacher Association (NSTA, 2012), which reports the standards for science teacher preparation in the USA. The second document is the research report written by Nezvalova (2007) on the competencies of constructivist science teachers. The third one belongs to National Research Council (NRC, 2012) that reports a new SE framework for K-12.

NSTA (2012) determined standards for science teachers' preparation as including different components such as having science content knowledge, using effective teaching methods to develop students' knowledge (content pedagogy), and planning appropriate learning environments for students. In the same manner, Nezvalova (2007) described basic competencies that especially constructivist science teachers should demonstrate. These competencies included for instance, understanding content knowledge, teaching nature of science, general skills of teaching and using effective assessment tools. NRC (2012) on the other hand, created a new framework for K-12 science education that focused on science, technology and engineering. This new framework included three major dimensions which are scientific and engineering practices, crosscutting concepts that combine science and engineering and core ideas in four fields which are physical science, life sciences, earth and space sciences and engineering, technology and applications of science. The first dimension is related to science practices to investigate and build models, theories and engineering practices to design and build systems. Second dimension which is cross cutting concepts which are *patterns, cause and effect, scale, portion, property, system and systems model, energy and matter, structure and function, stability and change* (NRC, 2012, p. 84). It is reported that these concepts enable students to make connection among various disciplines. The third dimension is related to disciplinary core ideas to teach students the sufficient core knowledge. This framework also has reflections for science teacher education. In the report, it is stated that teachers should be prepared to achieve this new framework. For instance, science teachers should have strong scientific understanding and they should know how to develop students' scientific and engineering practices, cross-cutting concepts, core ideas. That is to say, teachers should have specific pedagogical knowledge to support students' learning and they should know assessment approaches to measure students' thinking

The competencies for science teachers determined by NSTA (2012) and Nezvalova (2007) hold similar points (Table 4.1). For example, content knowledge of science, professional knowledge and skills, safety and welfare are the common competencies addressed in two documents. When the competencies given in Table 4.1 are evaluated critically, two major features were found related to the competencies of science teachers: 1. Science teachers' competencies are related only to cognitive aspects (knowledge, professional development and teaching skills), except ethical aspect of the competencies is included (under the title of safety) in the NSTA (2012) document. It is reported that; "*effective science teachers design and demonstrate activities in a P12 classroom to demonstrate ethical decision making with respect to the treatment of all living organisms in and out of the classroom*" (NSTA, 2012, para.4). This feature related to Science teachers' competencies is also reported by Kauertz, Neumann and Haertig (2012), according to the authors, for most of the cases, competencies are evaluated from cognitive domains and the affective domains are neglected. 2. There are a few items related to ESD competencies. For instance, in both documents (NSTA, 2012 and Nezvalova, 2007) it is emphasized that effective science teachers should promote knowledge and respect to all living things in the classrooms. However, competencies explored in the new framework of SE prepared by NRC (2012) included different items such as developing scientific and engineering practices, cross-cutting concepts and core ideas. The framework addresses several components related to systems thinking like patterns, flows, cycles and systems models for developing engineering design projects. Nevertheless, specific competencies for STs are not emphasized directly in this report.

The competencies for ESD educators (Table 4.1), however, are given by United Nations Economic Commission for Europe (UNECE 2011), depending on UNESCO (1996) framework. These include three essential characteristics of ESD: 1. *Holistic approach 2. Envisioning change: past, present and future 3. Achieving transformation*. The first characteristic which is holistic approach incorporates three interrelated components which are *integrative thinking, inclusivity and dealing with complexities*. Integrative thinking reflects systems thinking as a valuable tool. That is to say, integrative thinking or systems thinking emphasizes complex relationships among natural, social and economic systems and local and global aspects, different culture and different worldviews and the impact of today's decisions on the future. Inclusivity is related to embracing different perspectives and worldviews to create a sustainable future. Teachers should be aware of their own worldviews. Dealing with complexities is related to empowering students to realize connections between different concepts and ideas. Another essential characteristic is *envisioning change: past, present and future* that includes three components: learning from the past, inspiring engagement at present and exploring alternative futures. Learning from the past refers to critical analysis of past developments, their causes and consequences. Inspiring engagement at present emphasizes that ESD should encompass not only future generations' needs, but also all people's needs at present. 3. Exploring alternative futures is related to encouraging students to explore new pathways and create new vision for a sustainable future. The last characteristic is *achieving transformation* that includes three components, as well which are transformation of the meaning of an educator, transformation of pedagogy and transformation of the education system as a whole. Transformation of the meaning of an educator emphasizes that educators should be open to change in their own practices. Transformative pedagogy is related to developing students' creativity and encouraging them to imagine alternative ways of living. Finally, transformation of education system addresses the change in formal education system and educators should be open to change and transformation.

In addition, the competencies for ESD educators reflect the set of categories determined by UNESCO (1996) which are learning to know, learning to do, learning to live together and learning to be. The three competencies determined by UNECE (2011) are clustered under these four categories. Learning to know is related to understanding the role of the educator in the society. Learning to do refers to developing practical skills for ESD, and learning to live together is related to developing cooperation, partnership and interdependence. Finally, learning to be emphasizes the personality, autonomy and social responsibility related to sustainability. The remarkable point in ESD educator competencies determined by UNECE (2011) is that they include all learning domains such as cognitive, affective and action based ones. In other words, these competencies reflect the holistic nature of ESD and therefore, ESD educators should possess all domains of competencies. All the required competencies for science teachers and ESD Educators explored in the documents are presented in (Table 4.1)

Table 4.1

Summary of the Required Competencies for Science Teachers and for ESD Educators: Literature Review

Domains of Competencies for STs			Domains of Competencies for ESD educators
NSTA (2012)	NRC (2012)	Nezvalova (2007)	UNECE (2011)
1.Having content knowledge of science	1. Having strong scientific understanding	1. Understanding of science content	*1.Holistic Approach* a. Having integrative thinking/systems thinking and providing an integrative approach b. Inclusivity (embracing different perspectives) c. Dealing with complexities (providing students to engage in various concepts and ideas such as poverty and climate change)
2.Using effective teaching methods (pedagogy)	2. Developing students' scientific and engineering practices and cross-cutting concepts such as patterns, cause-effect, and systems model and core ideas.	2. Teaching the nature of science and history of science	2. *Envisioning change* A .Learning from the past (critically analyze and understand the root causes of the past developments) b. Inspiring engagement at present (emphasizing the needs of people at present and also the needs of future generations) c. Exploring alternative futures (addressing approaches to positive futures for human and nature)

Table 4.1 (Continued)

NSTA (2012)	NRC (2012)	Nezvalova (2007)	UNECE (2011)
3.Planing suitable learning environments	3. Having specific pedagogical knowledge to support students' learning and assessment approaches to measure students' thinking	3.Using scientific inquiry	*3.Achieving transformation of people, pedagogy and education systems* a. Transformation of what it means to be an educator (e.g., building positive relationship between educator and learner) b. Transformative approaches to learning and teaching (e.g., creating opportunities for learners to imagine alternative ways of living. c. Transformation of education system (e.g., being open to change, having collaborative skills)
4.Maintaining safety procedures in the class		4.Demonstrating general skills of teaching	
5.Demonstrating the impact of science course on students' learning		5. Planning and implementing an active curriculum	
6.Developing professional knowledge and skills		6. Using effective assessment strategies	

4.1.1.2 The Situation in Turkey: Current State of the Art

In Turkey, the required competencies of science teachers were determined by Ministry of National Education through a report prepared in 2008. According to Turkish Science Teachers' competencies report (MoNE, 2008), science teachers' main competencies are categorized in five components and 24 sub-components as presented in Table 4.2.

Similar to the above mentioned documents related to science teachers' competencies (Nezvalova, 2007; NSTA, 2012), most of the Turkish science teachers' competencies reported by MoNE (2008) are related to cognitive aspects such as general teaching and planning skills, scientific understanding and the relationship with the society (Table 4.2). Although they are not listed directly, the competencies given by MoNE (2008) contain several affective aspects which are "*to increase students' wonder of recognizing and examining the nature"* (p.5) and "*to cooperate with the families to develop students' environmental awareness and scientific literacy*" (p.10). In the document, it is emphasized that teachers are able to cooperate with community and families and develop projects in order to meet the social, economic and educational needs of the community in which the school is located. Nevertheless, there are still a few items related to ESD in the established competencies for Turkish science teachers (Table 4.2).

Table 4.2

Competences of Turkish Science Teachers (MoNE, 2008)

Main Components	Sub-Components	Description
1.Planing and organizing learning and teaching process	• To be able to plan the teaching process according to teaching program • To be able to organize learning environments according to teaching program • To be able to utilize teaching materials and sources to support teaching process	This content is related to planning and organizing science and technology teaching process, learning environment and using materials and sources for the teaching process.
2.Scientific, technological and social development	• To increase students' curiosity to examine their environment and develop sensitivity • To develop students' science process skills • To develop students' understanding of nature of science and history of science • To develop students' critical thinking skills • To be able to develop students' problem solving skills • To help students to be able to use scientific and technological concepts correctly and efficiently • To help students to be able to interpret the relationship between science and technology • To help students to be able to reflect Atatürk's views and thoughts about science • To develop students' understanding about the relationship between science, technology, environment and society • To take safety precautions in the science and technology teaching environment • To create activities suitable for the students with special needs and special education	This content is related to helping students to recognize and examine their environment, developing their science process skills, understanding the nature of science and history of science, critical thinking skills and problem solving skills, etc.

Table 4.2 (continued)

Main Components	Sub-Components	Description
3.Monitoring and evaluating development of students	• To monitor students' development • To evaluate the date obtained from measurement tools	This content is related to monitoring and evaluating students' development in the teaching process
4. The cooperation among school, society and family.	• To cooperate with the families for students' development about the subjects they need in their daily life such as environmental awareness and scientific literacy • To cooperate with the society to create culture and learning center in the schools. • To be a leader in the society • To increase students' awareness about the importance of national festivals and ceremonies	This content is related to cooperation with the families, developing leadership in the society, creating culture and learning center and organizations and ceremonies in the schools
5.Professional Development	• To determine professional competencies • To develop individual and professional development about science teaching • To utilize scientific research methods for professional development • To benefit from information technologies for professional development and communication	This content is related to teachers' professional development in order to support the teaching process

4.1.1.3 Detecting the gap: Competencies of STs versus Competencies for ESD Educators

Competencies defined for science teachers are listed in Table 4.1 and Table 4.2 along with those for ESD educators. Table 4.3 displays the comparison of science teachers and ESD educators' competencies as well as the gaps between these competencies. The gaps listed in Table 4.3 are composed of three headings which are *holistic approach, envisioning change and achieving transformation* which are the categories determined by UNECE (2011) for ESD educators stand for the gap between the competencies of science teachers and ESD educators. In summary, competencies for science teachers determined by NSTA (2012), Nezvalova (2007) and MoNE (2008) and competencies for ESD educators (UNECE, 2011) are completely different. However, the new SE framework prepared by NRC (2012) includes several items that are relevant to characteristics of ESD (Table 4.3). In the report, it is implied that future science teachers should be prepared to teach these items. For instance, NRC (2012) focuses on realizing the interrelationship among science, engineering and technology, understanding complex systems and developing systems thinking in engineering projects. UNECE (2011) also emphasizes the interrelationship among natural, economic and social systems, and systems thinking is seen as a key competency for ESD educators.

In general, competencies of science teachers do not include characteristics of ESD such as holistic approach, emphasizing the relationship among environment, society and economy, considering the relationship among past, present and future, understanding different groups, cultures (building empathic relationship) or being open to transformative learning and teaching approaches. In particular, systems thinking skill is one of the competencies for ESD educators that is needed to be emphasized since it is a component of holistic approach. Systems thinking is also addressed as an essential skill in SE research to be able to see the bigger picture, think holistically and build interconnectedness with the earth (e.g., Assaraf & Orion, 2010; Batzri et al., 2015; Littledyke, 2008).

In conclusion, it can be inferred that systems thinking is not the main issue of science teachers' competencies. That is, the results of the gap analysis show that a holistic approach through systems thinking is the major gap between the competencies set for ESD educators and those of science teachers.

Table 4.3

The Gaps between Required Competencies for STs and ESD Educators

Characteristics of ESD determined by UNECE (2011)	The inclusion of ESD competencies in the reports (NSTA, 2012; NRC, 2012; Nezvalova, 2007 and MoNE, 2008)	The Gaps
1.Holistic Approach a. Integrative thinking/systems thinking b. Inclusivity c. Dealing with complexities	a. NSTA (2012): not included b. Nezvalova (2007): not included c. MoNE (2008): not included d. NRC (2012): Included several items: • Interrelationship among science, engineering and technology • Understanding complex systems • Earth consists of interconnected systems • Developing systems thinking in engineering projects	NSTA (2012), Nezvalova (2007) and MoNE (2008) don't refer to competencies related to holistic approach. NRC (2012) implied several competencies related to holistic approach.
2. *Envisioning change* a. Learning from the past b. Inspiring engagement at present c. Exploring alternative futures	a. NSTA (2012): not included b. Nezvalova (2007): not included c. MoNE (2008): not included d. NRC (2012): Included several items: • Thinking about the future energy supplies coming from renewable sources • Considering our choices to reduce our impact on natural sources	NSTA (2012), Nezvalova (2007) and MoNE (2008) don't refer to competencies related to envisioning change. NRC (2012) implied several competencies related to envisioning change.
3.Achieving transformation of people, pedagogy and education systems a. Transformation of what it means to be an educator b. Transformative approaches to learning and teaching c. Transformation of education system	a. NSTA (2012): not included b. Nezvalova (2007): not included c. MoNE (2008): not included d. NRC (2012): Included an item related to personal choices • Considering the impact of everyday choices	NSTA (2012), Nezvalova (2007) and MoNE (2008) don't refer to competencies related to achieving transformation. NRC (2012) implied a competency (considering our choices) related to achieving transformation.

4.1.2 Tangible Part: Turkish SE and ESD Researchers' Opinions on the Competencies of STs

The purpose of the tangible part of gap analysis is to explore and confirm how the gap found between the competencies of science teachers and ESD educators is compatible with the current practice. SE and ESD researchers were interviewed for this purpose. Accordingly, tangible part included the interviews conducted with five SE and ESD researchers through the questions presented in methodology section 3.3.1.3 to investigate their opinions related to required competencies of Turkish science teachers and required competencies for being an ESD educator. The interviews were analyzed through content analysis and the results are presented below.

4.1.2.1 Required Competencies of Science Teachers in the 21st century in the Words of Scholars

SE and ESD researchers were asked about their ideas on the competencies science teachers should hold in the 21st century. Eight categories emerged as a result of the content analysis of the SE and ESD researchers' answers. The first five of the eight categories were the ones explored in the literature (e.g., MoNE, 2008; Nezvalova, 2007; NSTA, 2012) which are subject matter knowledge, pedagogical knowledge, technology knowledge, nature of science and problem solving skills. Yet, new categories emerged during the data analysis such as affective components, planning environmental education and holistic perspective (Table 4.4). According to frequencies presented in Table 4.4, the most frequently mentioned competency stated by the participants was holistic perspective. Competencies that science teachers should have in the words of SE and ESD researchers are presented in Table 4.4.

Table 4.4

The Competencies for Science Teachers in the Words of Scholars

Category	Sample Statements	Frequency
Subject Matter Knowledge Pedagogical Knowledge	P3: First, science teachers should have good subject matter knowledge. Pedagogical knowledge is one of the important competencies, as well. Teachers should know how to teach the subject according to grade level, and they should know which methods they should use.	4 (P1, P3, P4, P5) 3 (P3, P4, P5)
Technology Knowledge	P2: Science teacher should have knowledge about how to use technological tools in the classroom.	4 (P1, P2, P3, P4)
Nature of Science	P5: In addition to subject matter knowledge, science teachers should have an idea about the history of science. Chemistry, physics and biology are not separated subjects and a science teacher should be aware of history of science and philosophy of science.	3 (P1, P2, P5)
Holistic Perspective	P1: Science teachers should teach science subjects in a holistic way instead of separating them into parts in order to see the whole picture of the systems.	5 (P1, P2, P3, P4,P5)
Problem Solving	P1: Science teacher should teach students how to solve real life problems, and they should help students understand problems' scientific background and their impact on the environment and human.	2 (P1, P2)
Affective Components	P3: Science teachers should also teach students how to be a responsible citizen through the values like sharing, honesty, justice and sincerity.	2 (P2, P3)
Planning Environmental Education	P5: In the 21st century, environmental problems started to increase; therefore, science teachers should have an understanding and view about environmental education, and they should know how to increase students' environmental literacy.	1 (P5)

4.1.2.2 Competencies of Science Teachers to become ESD Educators: in the Words of Scholars

SE and ESD researchers were asked about the competencies science teachers should have to become ESD educators. Categories for the second question of the tangible part were similar with those suggested by Sleurs (2008) and UNECE (2011). Eight categories including cognitive and affective aspects were subject matter knowledge for ESD, pedagogical content knowledge for ESD, pedagogical knowledge for ESD, problem solving, citical thinking, holistic perspective, affective components and environmental awareness.

Among the above mentioned categories, the most frequently stated one for science teachers to become ESD educators was holistic perspective. Yet, affective skills, environmental awareness and critical thinking have also been mentioned by one or two participants such as P4 (Table 4.5).

Table 4.5

The competencies of science teachers to become ESD educators in the words of scholars

Category	Sample Statements	Frequency
Subject Matter Knowledge for ESD	P1: In addition to subject matter knowledge (physics, chemistry and biology), a science teacher should also know about economy, society and culture. In addition, in order to teach about sustainability, a science teacher should know the community culture and should provide appropriate learning conditions.	3 (P1, P4, P5)
Pedagogical Knowledge for ESD		3 (P1, P2, P5)
Cooperation and Networking	P5: For example, there is a plastic bag problem because people are using too many plastic bags. Students should understand social, economic, environmental and cultural aspects of the problem and be leaders for a change in the society. Therefore, teachers are required to encourage students to develop cooperation among themselves, their school and the community.	3 (P3, P4, P5)
Problem Solving	P1: Science teachers should have problem solving skills. They should be aware of real life problems that students might experience in daily life.	1 (P1)
Critical Thinking	P2: Science teacher should explain real life problems and be capable of discussing possible solutions. I mean that an ESD educator should have critical thinking skills.	1 (P2)
Holistic Perspective	P4: STs should know not only physics, chemistry, biology but also they should be aware of environment, technology. They should think in a holistic way.	5 (P1, P2, P3, P4, P5)
Affective Components (values, attitudes etc.)	P4: If a science teacher becomes an ESD educator, at first he/she should want this from the heart. This is very important because ESD needs too much time, love and willingness.	2 (P2, P4)
Environmental Awareness	P4: First, science teachers should have environmental awareness. Science teachers should be aware of the environment and should sacrifice for the environment.	2 (P3, P5)

4.1.2.3 Turkish Science Teachers' Position as ESD Educators in the Words of Scholars

All five participants' answers for the question related to Turkish science teachers' position as ESD educators were similar: "Turkish science teachers do not hold the competencies for being an ESD educator". Example excerpts are presented below:

> P4: I don't think science teachers in Turkey hold the competencies for being an ESD educator. According to my observations, they don't know what sustainability is, and they could not define the concept of ESD. Although there are several attempts in Turkey to realize ESD such as integrating sustainability into elementary science education program and research on ESD at universities and several implementations by NGOs, there are no attempts to develop science teachers' competencies in line with ESD. Therefore, I do not think science teachers in Turkey are ready to become ESD educators.

> P5: I don't think so because science teacher education programs do not include ESD. There are some courses at universities, but they are not sufficient. Teachers at universities do not have enough knowledge about sustainability, and they do not know how to teach it.

As far as the opinions of the scholars participated in this study are concerned, competencies of ESD educators that science teachers should have are subject matter knowledge, pedagogical knowledge, cooperation and networking, problem solving, critical thinking, holistic perspective, affective aspects (values, attitudes etc.) and environmental awareness (Table 4.5). Moreover, in line with the related literature (Assaraf & Orion, 2010; Sleurs, 2008; UNECE, 2011), all the scholars emphasize the importance of holistic perspective in SE as well as for ESD. Besides, according to the scholars of this study, science teachers should interpret the science subjects by considering the components of sustainability and the relationships among them, encouraging students to think about the components as presented in the quotation below:

P4: Science teachers should not only know physics, chemistry, biology but also environment and technology issues and should be capable of making conncetions among them.

4.1.2.4 Summary of the Gap Analysis Results

Ultimately, the results of content analysis of the interviews with Turkish SE and ESD scholars (tangible part) support the results of the theoretical part which suggests that the major competence science teachers required to have in the 21st century is holistic perspective, and that it is critical to grow competent science teachers for ESD. Furthermore, although the participants were not mentioned explicitly, the researcher interprets the overall outcome of the interviews as the major requirement for a science teacher to become an ESD educator is to have and convey systems thinking skills.

Systems thinking is related to seeing the whole picture, building interrelationships among the components of a system and understanding a phenomena in an integrated way (Senge, 2006; Sterling, 2003; Tilbury & Cooke, 2005). Similarly, ESD requires the facilitator to critically understand and evaluate the environmental, social, economic dimensions of the issues (Littledyke & Manolas, 2010). Likewise, understanding a natural system requires understanding the interrelationships among the earth systems and the human uses (Assaraf & Orion, 2010; Hmelo-Silver, Marathe & Liu, 2007). That is to say, if the issue is water cycle, a science teacher with systems thinking skills is expected to convey the knowledge that water quality and quantity in our taps are related to the amount of green house gases emitted to the atmosphere through our activities (such as mass production of meat and transportation) and also related to the sea level rise and climate refugee problem in Pacific Islands. In order to understand climate change and its impact on our planet and people's lives, students should be familiar with climate as a system (Shepardson et al., 2014). Instead of a linear understanding of a climate change as many science educators or environmental educators do, Shepardson et al. (2014) drew attention to systems thinking or systemic understanding of the climate. Therefore, gap analysis results reflect on the importance of systems thinking for science teachers and ESD educators.

4.2 Sealing the Gap: Results of the Pilot Study

As displayed in Figure 3.1, pilot study was designed to test data collection tools, to implement field trips and to determine PSTs' current level of STS. Accordingly, the pilot study was carried out with 29 PSTs as a part of the course titled as Environmental Science in 2013-2014 Spring Semester. Through the pilot study, 29 PSTs participated in two field trips in the context of "Sustainable Use of a Surface Water Body (lake) and "Transforming Waste to Wealth". Pilot data were collected through five tools as introduced in the previous section and STS has been measured through the tools (Table 4.6). In the pilot study, the quality and validity of five tools were tested and current systems skills of PSTs were determined. Results of the pilot study, therefore, are presented in line with the sequence of implementing the data collection tools introduced in the methodology section-3.3.2.2.

Table 4.6

The Tools and Corresponding STS Measured in the Pilot Study

	Essay	Case Study	The First Interviews	The Second Interviews	Field Reports	Concept Maps
STS-1 (Identifying aspects of sustainability)		√	√	√	√	
STS-2 (Seeing nature as a system)	√		√	√	√	
STS-3 (Identifying components of a system)		√	√	√	√	√
STS-4 (Analyzing interconnections)		√	√	√	√	
STS-5 (Recognizing hidden dimensions)			√	√	√	√
STS-6 (Recognizing own responsibility)				√	√	
STS-7 (Considering relationship between past-present and future)				√		
STS-8 (Recognizing cyclic nature)				√	√	√
STS-9 (Developing Empathy with people)			√	√		
STS-10 (Developing Empathy with non-human beings)				√		
STS-11 (Developing sense of place)				√		
STS-12 (Adapting systems thinking perspective to personal life)				√		

4.2.1 Essay Writing

Essay writing data of the pilot study were collected at the beginning of the course to measure the skill related to seeing nature as a system (STS-2) and the data were analyzed based on the themes and categories determined based on the coding booklet and the rubric developed by the researcher (Appendix E-F). Analysis of essay writing provided the researcher with two outcomes. Firstly, it was understood that STS-2 could be measured through one tool including one question ("What does a tree mean to you?"). In addition to *integral ecology* theme, researcher added another theme which is *human-nature relationship* to analyze writings in a more comprehensive way and evaluate STS levels of participants (mastery, developing, emerging and pre-aware).

Secondly, current level of STS-2 of PSTs was measured before the main study was conducted. Table 4.7 summarizes the results of essay writing.

Table 4.7

The Results of Essay Writing Analysis in the Pilot Study

The Tool: Essay writing					
STS	Themes and Categories		PSTs	Sample Statements	STS Level
	1.Integral Ecology	**2.Human-Nature Relationship (HNR)**			
STS-2: Seeing Nature as a System	**1a. Identifying two aspects of integral ecology** (e.g., behavioral (source of oxygen, wood, food) and experience (family**)**	**2a. Holistic view**	12 PSTs	PST12: Trees are like a family. When one person is absent in a family, this affects the whole family. This is the same for trees. Destruction of one tree influences the whole world. Trees provide oxygen, food, shelter for many species. Destruction of the trees gives harm to the whole balance in the world.	Developing
	1b. Identifying one aspect of integral ecology (e.g., behavioral (source of heat, food)	**2 b. Mechanistic view**	17 PSTs	PST4: Trees are source of life. Trees don't have only one function. Trees hold an important place in our life. We are benefiting from trees in everything such as food, heating, paper and breathing.	Emerging

According to results of the data analysis of the essays written by 29 participants, STS level of 12 participants were found as *developing* based on the rubric (Appendix E). That is, these participants' STS level was found in *the category of identifying two aspects of integral ecology* based on the theme of integral ecology. They described nature in terms of technical point of view such as trees as source of oxygen (behavioral), food and subjective perspective such as trees are like a family (experience). Their STS level was also found in the category of holistic view based on the theme of human-nature relationship. They noted that trees protect the natural balance in the Earth. On the other hand, 17 participants' STS level was found as *emerging*. That is, their STS level was found in the categories of *identifying one aspect of integral ecology and mechanistic view*. They explained nature in terms of technical point of view such as trees as source of heat or subjective point of view such as trees as source of joy. Furthermore, they mostly emphasized trees from a mechanistic view rather than describing a tree as a living system. Therefore, their level of STS-2 was evaluated as *emerging*.

In conclusion, results of the essay writing presented two outcomes. First, the results gave an idea about PSTs' current level of STS (seeing nature as a system). Second, the results supported that essay writing could be used as a tool to measure PSTs' STS in the context of SE and ESD. The reason for that is the responses to the question of "What does a tree mean to you?" provided rich information regarding participants' skills. Furthermore, data analysis of participants' writings gave information about the components of integral ecology and interpretation of human-nature relationship, and thus, enabled the exploration of PSTs' level of STS.

4.2.2 Case Study

Case study analysis during the pilot study enabled the researcher to test the case as a tool to measure three STS (STS-1, STS-3 and STS-4) and to evaluate the current STS levels of PSTs based on the rubric. Table 4.8 presents the themes, categories, rubric levels and sample statements related to data analysis of the cases. Figure 4.2 provides all participants' STS levels in the case study analysis. The case *(Çorum Agricultural Land-Unfilled Emptiness)* was related to the deterioration of agricultural lands by the companies for the brick production and the impact of this issue on people and environment.

Table 4.8

The Results of Case Study Analysis in the Pilot Study

Case Study Analysis				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-1: Identifying aspects of sustainability	**Aspects of Sustainability** **a.Identifying all aspects of sustainability** (e.g,. environmental (destruction of the environment), social (local people's right to live) and economical (production)	2 PSTs	PST2: The company is taking villagers' land because they want to meet the demands of people cities. Villagers are selling their land and move to cities and become consumers because health and education are not good in the village. The population is increasing in the cities and production is decreasing. Thus, they become a consumer in the cities. Furthermore, we do not like the company because they destroy the environment. On the other hand, they need raw material to maintain their production.	Mastery
	b.Identifying one aspect of sustainability(e.g., environmental (destruction of the environment)	17 PSTs	PST1: This case is the story of selfish people who are destroying our environment for their own benefits. These people do not have sustainable development awareness. They have short term thinking.	Emerging

Table 4.8 (Continued)

Case Study Analysis				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-3: Identifying components of a system	**Components of a system** **a.Multiple Components** (e.g., company, villagers, cities, environment etc.)	2 PSTs	PST2: The company is taking villagers' land as they want to meet the needs in the cities. Villagers are selling their land and move to cities and become consumers because health and education are not good in the village. The population is increasing in the cities and production is decreasing. Thus, they become a consumer in the cities. Furthermore, we do not like the company because they destroy the environment. On the other hand, they need raw material to maintain their production. For me, people could be more responsible individuals and prefer living in a simple way.	Mastery
STS-4: Analyzing interconnections among the aspects sustainability	**Interconnection among the aspects of sustainability** **a.No interconnection**	10 PSTs	PST-11: This is a sad story. I am sure that there are many stories like this in other places. This case shows that we don't think about the future, and we don't know what sustainability is.	Pre-aware

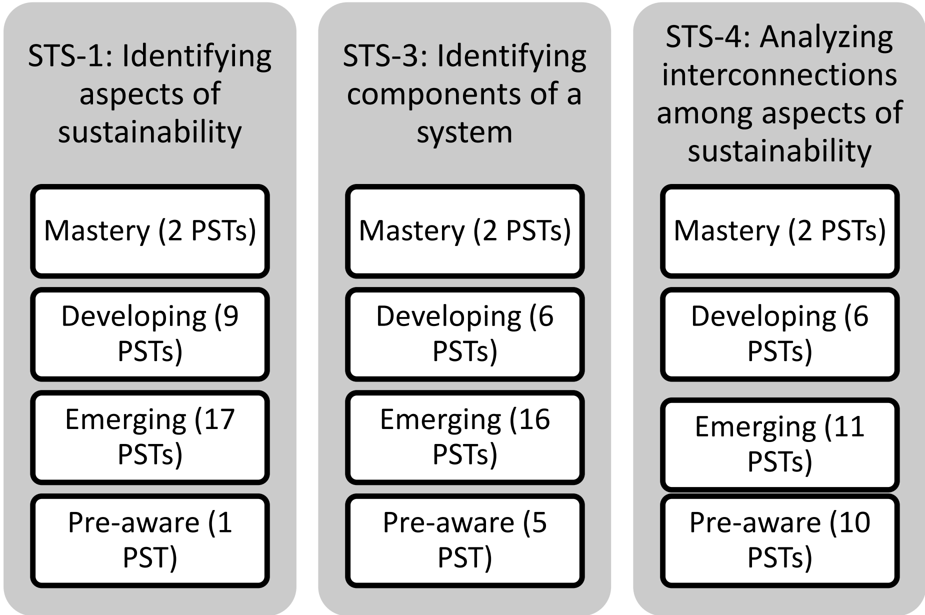

Figure 4.2 Participants' STS levels based on the Case Study Analysis Results

Results of case study analysis revealed that participants have different levels of STS. According to the data presented in Table 4.8, only two participants had the category of *identifying all aspects of sustainability.* She evaluated the case in terms of social, economic and environmental aspects of sustainability. She referred to how destruction of agricultural lands influences people's economic and social lives. Therefore, her level of STS was evaluated as *mastery*. 17 participants, on the other hand, were in the category of *identifying one aspect of sustainability.* These participants highly emphasized environmental aspect of sustainability such as destruction of the environment by the factories and companies. Therefore, their level of STS was found as *emerging.* Only one participant's level of STS was found as *pre-aware* (Figure 4.2). That means that most of the participants have an idea about what sustainability is.

As far as the situation for the skill for identifying components of a system (STS-3) is considered, eight participants' level was found in the *category of multiple* *components*. That is, these participants described the case as encompassing several components such as factories, company, agricultural lands, cities etc. Their level of STS was found as *mastery or developing* based on their explanations. On the other hand, 16 participants' level of STS was found in the *category of single component* and as *emerging.* That is, they evaluated the case from a single point of view such as villagers living in the area or destruction of the agricultural lands. Five participants could not describe any specific components related to the case; therefore; their level of STS was evaluated as *pre-aware.*

Likewise, the results revealed that only two participants' skill of analyzing interconnections among the aspects of sustainability (STS-4) was in the category of *Interconnection among the all aspects of sustainability* and in the *mastery* level. As mentioned before, two participants could define whole aspects of sustainability and the interactions among the aspects. For instance, PST-2 mentioned that destruction of the agricultural lands explained in the given case promotes local people to move to the cities, and this brings new economic problems in the cities. On the other hand, eleven participants could not make any interconnection among the aspects of sustainability and their level of STS was found as *pre-aware.*

Briefly, according to results, most of the participants evaluated the case as incorporating environmental aspect of sustainability (egg. destruction of the environment) or sometimes economic aspects. That is to say, they are aware of what sustainability is, yet they struggled to identify three aspects of sustainability. They mentioned destruction of the environment because of economic concerns of the companies frequently instead of emphasizing social, economic and environmental concerns in the given case. They also struggled to explain how social, economic and environmental aspects of sustainability are related to each other and contribute to the problem in the given case.

In conclusion, results provided an idea about PSTs' current level of STS (STS-1, STS-3 and STS-4) and results supported that case study analysis could be used as a tool to measure STS of the PSTs in the context of SE and ESD. Data analysis of the participants' evaluations about the case provided rich information about how they could determine the components of the case and analyze the case from sustainability perspective, and thus, PSTs' level of STS were defined.

4.2.3 Interviews

4.2.3.1 Interview-I

It was attempted to measure six STS (STS-1, STS-2, STS-3, STS-4, STS-5, and STS-9) through the first interviews which were held with six participants after the implementation of essay writing and case study analysis. Through conducting interviews, it was aimed to get detailed information about participants' STS levels. Data analysis of the first interview revealed that only one participant's skills (STS-1, STS-3, STS-4, STS-9) were found in the *mastery* level (Table 4.9). Other five participants' STS levels were found in different levels (developing, emerging and pre-aware).

Table 4.9

Results of the Interview-I

Interviews-I					
STS	Themes and Categories		# of PSTs	Sample Statements	STS Level
STS-I: Identifying aspects of sustainability	**Aspects of Sustainability** **a.Identifying two aspects of sustainability** **(**e.g., destruction of the environment, reduction of the production)		3PSTs	P5: It gives harm to sustainability. Firstly, the land is destroyed because of the factories. Factories emit CO2 and they cause greenhouse effect and global warming. Moreover, this situation does not allow villagers to use their land. It reduces production and harms sustainability in the agriculture.	Developing
STS-2: Seeing nature as a system	**1.Integral Ecology** **1a.Identifying one aspect of integral ecology** (e.g., experience-childhood memories)	**2.Human-Nature Relationship** **2a.Mechanistic View**	4PSTs	P2: Trees remind me a place where I sit with my friends. When it is rainy, trees show their beauty, health, peace and serenity.	Emerging

Table 4.9 (Continued)

Interviews-I				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-3: Identifying components of a system	**Components of a system** **a.Multiple Components (**e.g., villagers, company, nature)	4 PSTs	P5: There are villagers, land and companies that make profit here. There is government, too. There is policy, nature and land. Land is destroyed. This case includes multiple aspects.	Developing
STS-4: Analyzing interconnections among the aspects sustainability	**Interconnection among the aspects of sustainability** **a.Interconnection among the two aspects of sustainability** (e.g., economy and environment)	3 PSTs	P3: For me, it is important to increase people's awareness instead of protecting the environment with the laws. In Turkey, people have serious economic problems. In this case, we see in the case that villagers are selling their land because of their economic concern. They are right because they consider the future of their children, but they don't think about their grandchildren. They have short term thinking.	Developing

Table 4.9 (Continued)

Interviews-I				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-5: Recognizing hidden dimensions	**Hidden dimensions in a system** **a.Explaining hidden dimensions** (e.g., powerful economy)	3 PSTs	P4: When I mentioned economically powerful people, I did not mean only manufacturers. There is more powerful economy here. For example, the government wants to develop the country and destroy buildings and build new ones again. This is the government policy.	Emerging
STS-9: Developing empathy with other human beings	**Empathy with people** **a.Considering other people's perspectives in a simple way**	3 PSTs	P1: There is an economic concern. I think... what is the need of the villager? How do they earn their life? If someone gives more money to them, they want to sell their land. Their aim is to earn their life. If they earned much more, they would not think like that.	Developing

In the first interviews, participants were asked detailed questions related to essay writing and case study analysis. For instance, they were asked about *the components in the given case as well as the hidden components in the case.*

The first skill explored in the first interviews was identifying aspects of sustainability (STS-1). The data analysis of the interviews revealed that only one participant among six could identify three aspects of sustainability (environmental, economic and social) related to given case (*Çorum Agricultural Land-Unfilled Emptiness*). Therefore, her level of STS was evaluated as *mastery*. Three participants, on the other hand, evaluated the case from two aspects of sustainability (e.g., environment and economy), and their level of STS was evaluated as *developing.* For example, P5 mentioned that destruction of the agricultural lands affects both environment, and economy and it harms sustainability of the agriculture. Yet, two participants among six only described one aspect of sustainability (environmental) and their level of STS was found as *emerging* (Table 4.9).

Another skill explored in the interviews was seeing nature as a system (STS-2): According to results only one participant among six could describe nature as a systems by considering technical point of view (behavioral) like trees as source of oxygen (behavioral) and subjective point of view such as trees in their childhood memories (experience). She also tried to describe nature from a holistic view, and therefore, her level of STS was evaluated as developing. On the other hand, four participants struggled to describe nature as a system. That is to say, they explained nature in terms of subjective point of view like trees providing peace and beauty for people. Moreover, they explained nature through mechanistic view instead of describing nature as a living system. Therefore, their skill was assigned to *emerging* level. As one participant could not refer to any particular aspect of integral ecology, his level of STS was evaluated as *pre-aware* (Table 4.9).

Identifying components of a system (STS-3): Five participants evaluated the case *(Çorum Agricultural Land-Unfilled Emptines)* as including multiple components such as villagers, companies, government and nature. As they tried to explain several components related to given case their level of STS was found in the *developing* level. On the other hand, one participant explained the case as including single component (the role of the companies), therefore, her level of STS was evaluated as *emerging.*

Analyzing interconnections among the aspects of sustainability (STS-4): Only one participant among six could analyze interconnection among the all aspects of sustainability. She evaluated the case by considering the relationship among social, economic and environmental aspects and her level of STS was found as *mastery.* On the other hand, three participants could analyze interconnections among two aspects of sustainability (e.g., environment and economy). For instance, P5 noted that villagers make a living through agriculture, therefore, they have economic concerns, and for this reason they may want to sell their land to the companies. Three participants' STS level was evaluated as *developing.* As one participant could not refer to any specific interconnection, her level of STS was found as *pre-aware.*

Recognizing hidden dimensions (STS-5): The results revealed that three participants struggled to explain hidden dimensions and their level of STS was found as *emerging.* Other three participants could not refer to any hidden dimensions related to case and their level of STS was evaluated as *pre-aware*. As presented in Table 4.9 for instance, P-4 mentioned that there is an economic power which has an influence on the problem in the given case, yet he could not refer to any other hidden dimensions such as the impact of climate change. Any participants' STS level was evaluated as *developing or mastery.*

Developing empathy with people (STS-9): Only one participant's level of STS was found as *mastery* since she was in the category of *considering other people's perspectives in a complete way.* Three participants, on the other hand, held the category of *considering other people's perspectives in a simple way* and their level of STS was found as *developing.* As presented in Table 4.9 P1 simply explained that villagers had to sell their land because of their economic concerns and in order to meet their needs. Two participants, on the other hand considered other people's perspective in one side (considering villagers in the given case). Their level of STS was found as *emerging.*

4.2.3.2 Interviews-II

It was aimed to measure twelve STS (STST-1 to STS-12) through the second interviews and interviews were held with five participants after the two field trips; *1.Sustainable Use of a Water Body (lake) and 2. Transforming waste to wealth***.** According to results, any participants' levels of STS were in the mastery level. Only P9's empathy skill (STS-9) was found in the *mastery* level. Participants' STS levels were frequently evaluated as *developing and emerging*. Table 4.10 presents themes, categories and STS levels based on the skill measured for the first time in the second interviews (STS-6, STS-7, STS-8, STS-10, STS-11 and STS-12).

Table 4.10

Results of the Interviews II

Interviews-II				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-6: Recognizing own responsibility in the system	**Recognizing own Responsibility** **a.Stating own responsibility**	1 PST	P7: I need to draw the attention of the students and increase their motivation. I really liked going to Eymir and doing compost. I remember everything is related to Eymir very well. I reflected it to my life directly. Therefore, I was really interested in these topics.	Developing
STS-7: Considering the relationship among past, present and future	**Making connections among the past, present and future** **a.Considering two time spans simply**	2 PSTs	P10: I think that Eymir will be protected in the future because the water is clean. If there is no drought, Eymir will stay as a natural environment	Emerging
STS-8: Recognizing cyclic nature of the system	**Cycling nature of the system** **a.Explaining cycling nature of the system**	2 PST	P11: Nothing is waste in nature. There is a cycle and something we have used before is recycled again	Developing

Table 4.10 (Continued)

Interviews-II				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-10: Developing empathy with non-human beings	**Empathy with non-human beings** **a.Considering non-human beings**	1 PST	P8: I have always wondered how the fish are affected in the lake in terms of water quality parameters. I wondered what PH is appropriate for the fish. I have not searched yet, but I was thinking of them.	Emerging
STS-11: Developing sense of place	**Sense of place** **a.Multidimensional sense of place (**e.g, psychological, biophysical)	1 PST	P9: During my first visit to Eymir, I only thought the place as a social activity. Yet, during the field trip, I realized that Lake Eymir is a natural place and understood how it contributes to our life.	Developing
STS-12: Adapting Systems thinking perspective to personal life	**Personal actions for sustainability** **a.Simple actions for sustainability**	3 PSTs	P9: I try to be careful with my waste. I try to identify what is harmful or not. I also sometimes explain composting process to people.	Emerging

According to results of the interview-II, for example, for the skill of recognizing own responsibility (STS-6), four participants' skill was found in the category of *stating own responsibility* and in the *emerging* level and only one participant's level of STS was evaluated as *developing.* For instance, PST-7 expressed that while he was in Eymir, he realized that there was a connection between his life and Eymir as a natural system (Table 4.10).

Recognizing cycling nature of the system (STS-8): According to Table 4.10 two participants among five could explain cycling nature of the system in a simple way. For instance, PST-11 mentioned that there were cycles in nature and everything was recycled. She tried to explain cycling nature of the system by giving simple examples from nature, therefore, her level of STS was evaluated as *developing*.

Sense of place (STS-11): One participant's STS was evaluated in the category of *multidimensional sense of place* and in the *developing* level. For instance, PST-9 described Eymir in terms of psychological dimensions such as going to Eymir for social activities and biophysical dimensions such as realizing Eymir as a natural place (Table 4.10). Two participants' STS were found in the *single dimensional sense of place* and in the *emerging* level. They mostly described Eymir in relation to their personal experiences such as Eymir as a relaxing environment (psychological).

Adapting systems thinking perspective to personal life (STS-12): Accordingly, the results revealed that three participants' level of STS was found in the category of *simple actions of sustainability* and as *emerging.* To be specific, three participants mentioned about simple actions for sustainability such as reducing waste and recycling. Two participants, on the other hand, did not mention any particular action related to sustainability and their level of STS was found as *pre-aware.*

Accordingly, two interview results (Interview-I and Interview-II) provided an idea about current STS level of the PSTs. Moreover, the results supported that interviews could be used a tool to measure twelve STS of the PSTs in the context of SE and ESD. Data analysis of the interviews provided in-depth information regarding participants' STS and enabled the exploration of their level of STS.

4.2.4 Field Reports and Concept Maps

Two field reports for the trips titled as *Sustainable Use of a Surface Water Body (lake) and Transforming Waste to Wealth* were designed as STS measurement tools. Based on the questions in the field reports, (Appendix D) seven STS (STS-1, STS-2, STS-3, STS-4, STS-5, STS-6 and STS-8) were attempted to be measured. Accordingly, data analysis of the field reports revealed that five participants' STS levels were found in the *emerging or developing* levels. According to Table 4.11, for instance, one participant among five mentioned how his view of nature (STS-2) changed after the field trip to Lake Eymir. Before the trip he described Lake Eymir through subjective perspectives such as Eymir as a relaxing and silent place. Yet, after the trip, he described Eymir as a living system (holistic view) as encompassing environmental value. Therefore, his level of STS was evaluated as developing.

Moreover, according to analysis of the field reports, participants struggled to analyze relationships among the aspects of sustainability. For instance, P7 described multiple components related to Eymir such as government policy, climate change, and living species; therefore, the level of STS-3 was found as *developing.* However, he struggled to explain the interconnections among the aspects of sustainability (environment, economy). Therefore, his level of STS-4 was evaluated as *emerging.* Moreover, participants recognized cycling nature of the system after the field trips. As displayed in Table 4.11, P8 mentioned that how natural cycles were destroyed because of unsustainable practices and suggested composting as one of the solutions to protect natural cycles. As she could recognize cycling nature of the system (STS-8), her level of STS was found as *developing.*

Table 4.11

Results of the Field Reports

Field Reports					
STS	Themes and Categories		# of PSTs	Sample Statements	STS Level
STS-2: Seeing nature as a system	**1.Integral Ecology**	**2.Human-Nature Relationship**	1 PSTs	P9: When you first asked me the meaning of Eymir, I only thought of my happiness there, but I realized that I don't think other living things' happiness as they suffer from environmental pollution. Now, Eymir reminds me all the living things and water. I believe that if we don't realize the importance of living things and continue destroying their life, we will also suffer from its consequences in the future. (after the field trip)	Developing
	1a.Identifying two aspects of integral ecology (subjective, behavioral)	**2a.Holistic View**			
STS-3: Identifying components of a system	**Components of a system**		3 PSTs	P7: In Turkey people are not so much aware of environmental issues, but I am proud of my university and I believe that they will protect Eymir. In addition to negative government policies in Turkey, we have another problem: climate change. In Ankara summers are very hot and dry, so Eymir can lose its water day by day and all living species could be in danger.	Developing
	a.Multiple components				
STS-4: Analyzing interconnections among the aspects sustainability	**Interconnection among the aspects of sustainability**		2 PSTs		Emerging
	a.Separated explanation				

Table 4.11 (Continued)

Field Reports				
STS	Themes and Categories	# of PSTs	Sample Statements	STS Level
STS-6: Recognizing own responsibility in the system	**Recognizing own responsibility** **a.Not stating own responsibility**	2 PSTs	P10: We have to protect the biogeochemical cycles because we break them. Firstly, we should be aware of the importance of water. We should not overconsume water and not pollute water because there is a balance in nature. Moreover, when we buy a new product, we should think about its production process. How much water is used for this production? What is the environmental impact of this product? We should be more aware of these.	Developing
STS-8: Recognizing cyclic nature of the system	**Cyclic nature of the system** **a.Explaining cycling nature of the system**	2 PSTs	P8: Natural cycles never end up. However, people's unsustainable behaviors damage the cycles. For example, people produce materials that are not decomposed in nature such as plastic. Also, they produce new chemicals which pollute air and water. These global problems destroy the natural cycles. Composting could be a solution. Composting provides sustainable use of natural resources.	Developing

Furthermore, PSTs were asked to draw concept maps in their field reports related to Lake Eymir. Concept maps were evaluated based on the three STS (STS-3, STS-5 and STS-8) and evaluated based on the concept map rubric (Appendix E). In order to analyze concept maps, the themes of number of components, connections, hidden dimensions and complexity were used (Table 4.12). Based on the analysis of concept maps, two participants' concept maps were evaluated as *developing.* In other words, they showed most of the components and connections related to the natural system (Eymir). For example, as displayed in Table 4.12 and Figure 4.3, PST-7 incorporated social, environmental and economic components related to Eymir and showed connections among these components.

On the other hand, P8's concept map was evaluated as *emerging.* That is to say, she demonstrated several components related to Eymir such as social (e.g., visitors) and environmental (e.g., trees, animals), yet she could not show relationships among these components clearly. She did not create a concept map as including complex relationships (Figure 4.4); instead, she displayed linear, hierarchical relationships in her map. Table 4.12 presents concept map analysis of two participants and Figure 4.3/4.4 display these participants' concept map drawings.

Table 4.12

Two participants' concept map analysis results (Pilot Study)

PSTs	Developing STS: Results of the Concept Maps through Module-II Themes					STS Level
	Components of the system	**Hidden Dimensions**	**# of Components**	**# of Connections**	**Complexity**	
PST-7	e.g., Lake Eymir, visitors, business, administration, restaurants, trees, waste etc.	e.g,. administration	26	26	Linear relationships. Needs to be developed	Developing
PST-8	e.g., Lake Eymir, visitors, workplace, trees	No hidden dimension	17	15	Linear shape and no complexity	Emerging

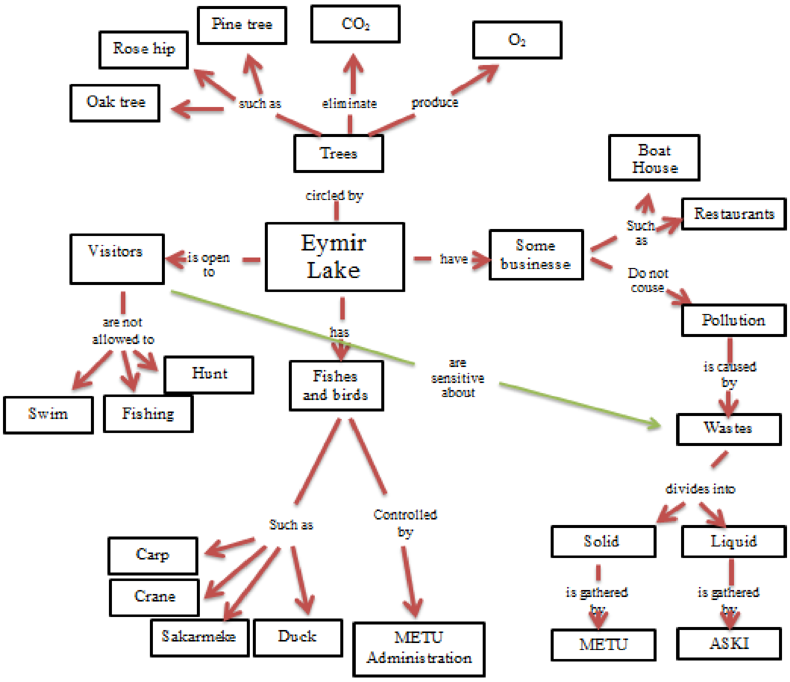

Figure 4.3 Concept map drawing (P7)

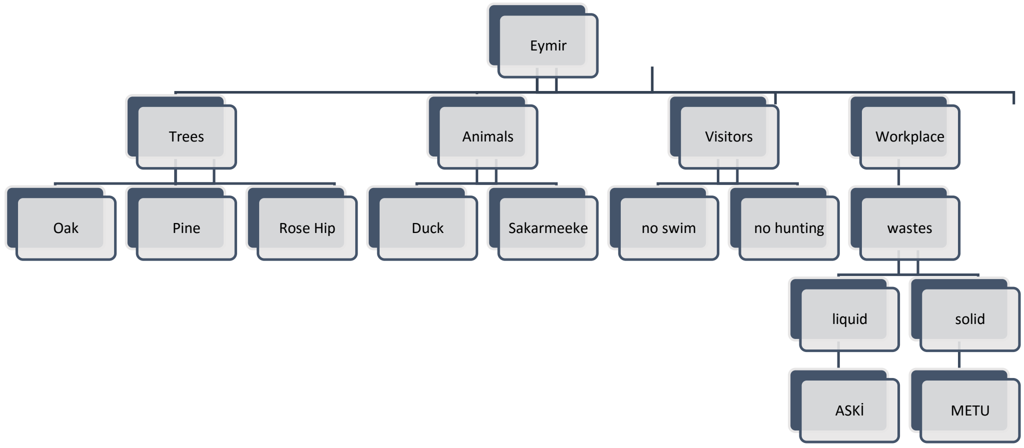

Figure 4.4 Concept map drawing (P-8)

In conclusion, results in the pilot study illustrated that systems thinking skills could be measured through essay writing, case study analysis, interviews, field reports and concept maps. All the data collection tools showed that PSTs' STS were especially found in low levels (emerging, pre-aware) and their skills need to be developed. Furthermore, the results indicated that PSTs who were involved in the field trips during the course developed their several STS such as the skill of seeing nature as a system (STS-2). Field trips contributed to their understanding of the natural systems, human-nature relationships and cycling nature of the system. For this reason, field trips hold a potential to develop STS levels of the PSTs. Concept maps also provide additional data about the skill of identifying components and connections in a system, identifying hidden dimensions and cycling and complex nature of the system.

4.2.5 Lessons Learned From Pilot Study

The questions planned to be answered through conducting the pilot study were related to testing the data collection tools developed for this study, pilot implementation of the outdoor field trips and determining current level of STSs of PSTs (Figure 3.1). The lessons learnt in accordance with the above targets considered are presented in the following section and the readjustments done according to the lessons learnt are reported.

4.2.5.1 Data Collection Tools

The purpose of the pilot study was initially to test data collection tools. Each tool was used to measure specific STS as explained in the previous section. For instance, essay writing was prepared to measure the skill of seeing nature as a system (STS-2), and at the end of the pilot study, it was understood that STS-2 could be measured through asking one question ("What does a tree mean to you?") and requesting PSTs to write an essay about it. Case study analysis was revealed that three STS (STS-1, STS-3, STS-4) could be measured through asking participants to evaluate the given case in terms of their opinions and views. Semi-structured interviews revealed that twelve STS could be measured. The first interviews measured STS based on the case study analysis and essay writing, and the second interviews measured STS based on the field trips. The first interview questions could be developed and more questions could be added in order to measure more STS.

Furthermore, field reports measured seven STS and provided data about STS level of PSTs. It was found out that field reports also hold a potential to evaluate STS of PSTs. For instance, some participants gave much more information in the field reports.

Accordingly, researcher decided to use all these data collection tools in the main study; however, some adjustments were made in the interview questions and case study analysis in the main study. Case study analysis included more challenging and complex issues. Furthermore, some interview questions were changed and new questions were added to be able to measure STS in a more comprehensive way.

4.2.5.2 Field Trips and Field Reports

In the pilot study, there were two field trips and PSTs completed two field reports related to these field trips. The first one titled as Sustainable Use of a Surface Water Body (Lake Eymir) included three stages (ecosystem of Eymir, water quality and human use), and PSTs were asked to choose one of these stages and work with their group. However, because of the limited time in the lecture (3 hours), PSTs did not have opportunity to work in each stages of the trip. During the interviews, they also expressed their concern, and they would like to work in three stages in order to learn more about the natural system in Eymir. These feedbacks provided researcher an opportunity to develop field trips before the main study started. In the main study, the researcher carried out Eymir field trip in four weeks so that PSTs could have time to examine Eymir from different aspects.
Researcher also developed the second field trip titled as “Transforming waste to wealth” and included gardening activities as well.

4.2.5.3 Rubric Development

In order to analyze results in the pilot study, researcher developed a rubric to measure STS. At first, the rubric included three levels (mastery, developing and emerging); however, through the pilot analysis, the researcher realized that these three levels were not sufficient to show the STS level of PSTs. With the suggestion of an expert in ESD, the researcher decided to add a new level which was called as “pre-aware”. In this way, final rubric consisted of four levels (mastery, developing, emerging and pre-aware). Data analysis in the pilot study and main study was implemented based on the four levels of the rubric. Researcher did not make any change in the concept map rubric.

4.2.5.4 Participants

In the pilot study 29 PSTs attended in the essay writing, case study analysis and field trips. Interviews were conducted with eleven participants among 29. In order to reveal STS profile of each PST, it was decided to study with a small number of participants in the main study. For this reason, single case embedded design with multiple units of analysis was decided as the research design of the main study.

4.2.5.5 Current Level of Systems Thinking Skills

Pilot study provided researcher to assess current level of STS of PSTs before the main study started. As expected, except one or two participants, none of the participants' level of STS was found as mastery. Data analysis of the measurement tools revealed that PSTs do not have a comprehensive sustainability view and systemic perspective. During the case study analysis and interviews, they struggled to make connections between the issue, their life, global problems and past, present and future. When compared to other STS skills, the skills of considering the relationship among past, present and future (STS-7), developing empathy with non-human beings (STS-10), developing sense of place (STS-11) and adapting systems thinking perspective to personal life (STS-12) were frequently found in the emerging and pre-aware level. Furthermore, pilot study results shed light on the fact that PSTs' STS need to be developed.

In conclusion, conducting a pilot study helped researcher realize the challenges in the current study and find out solutions to them. Furthermore, pilot study increased researcher's encouragement, morale and motivation to continue this study. Pilot study also promoted rigor and trustworthiness of the main study.

4.3 Results of the Main Study

The main study was designed and implemented in line with the results of gap analysis as a result of which system thinking skills (STS) was found as the major requirement for a science teacher to become an ESD educator. Accordingly, the results of the main study are presented in terms of PSTs' STS development through the outdoor ESD course. This chapter, therefore, is comprised of two parts, answering the research questions:

1. How can PSTs' systems thinking skills be developed through the outdoor based ESD course?
2. To What extent do PSTs reflect their systems thinking skills for instructional planning under the light of the outdoor ESD course?

4.3.1. How can PSTs' Systems Thinking Skills be Developed through the Outdoor Based ESD Course?

Pre-service science teachers' STSs were intended to be developed through the outdoor based ESD course that was designed by the researcher and that is comprised of three modules (Method-Section 3.3.5.2). The results obtained from the implementation of the course are presented below in line with the course schedule. Therefore, similar to the course schedule, the results related to development of PSTs' system thinking skills are presented in three parts (Table 4.13). The first part is comprised of the results related to initial states of the PSTs (Module-I) as far as their STS are concerned. The instruments used to measure initial STS were essay writing, case study analysis and interview I which were implemented during the first two weeks of the course.

The second part is comprised of those of Module-II of the course: Results related to developing PSTs' STS on the sustainable use of a system, which were obtained through three instruments which are field reports (I, II, III) and interview-II along with accompanying concept maps.

The third part of the results is comprised of the results related to the Module-III of the course which targeted to develop PSTs system thinking skills through sustainability solutions and measuring the development, which were gathered through three instruments: field report IV, interview-III along with accompanying concept maps (Table 4.13).

Table 4.13

Results of the Main Study as presented in line with the Outdoor ESD Course Schedule: Related Instruments and Research Questions

Course Schedule	Instrument used to measure STS	Research Question
MODULE I. Determining Initial State of STS (February 20- March 6 2014)		
WEEK-I Warming up	Essay Writing (What does a tree mean to you?)	
WEEK-II Thinking exercise	Case Study Analysis-I (We are losing our pastures in Turkey) Interview-I	
MODULE II. Developing STS: What is sustainable use of a system? (March 13- April 10 2014)		1. How can PSTs' systems thinking skills be developed through the outdoor based ESD course?
WEEK-III The need for systems thinking		
WEEK-IV Sustainable Use of A Lake (Ecosystem of Lake Eymir)		
WEEK-V Sustainable Use of a Lake (Water Quality Monitoring in Lake Eymir)	Field Reports (I-II-III) Interview-II + CM-I	
WEEK-VI Sustainable Use of a Lake (Human Use in Lake Eymir)		
WEEK-VII Discussion- Systems thinking exercise through the results of Module II.		

Table 4.13 (Continued)

Course Schedule	**Instrument used to measure STS**	**Research Question**
MODULE III. Developing STS: Sustainability Solutions (April 20- June)		
WEEK-VIII Sustainability Solutions: Working in the Backyard WEEK-IX Sustainability Solutions: Working in the Backyard WEEK-10 Discussion- Systems thinking exercise through the results of Module II WEEK-XI Completing the Circle: Sustainable uses - sustainable solutions	Field Report-IV Case Study Analysis-II (The most expensive meat is consumed in Turkey) Interview-III + CM-II	1. How can PSTs' systems thinking skills be developed through the outdoor based ESD course?
Final Project	Lesson Plan	2. To What extent do PSTs reflect their systems thinking skills to instructional planning under the light of the outdoor ESD course?

4.3.1.1 Determining the Initial State of STS (Module-I)

The initial state of system thinking skills of the PSTs were determined through essay writing, case study analysis and interviews. The skills measured by these instruments are given in Table 4.14 below:

Table 4.14

STS Measurement (Module-I)

	Essay Writing	Case Study Analysis	Interviews-I
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 between past, present and future)			√
STS-9 (Developing empathy with other people)			√

4.3.1.1.1 Initial state of STS measured through Essay Writing

Essay writing was used in order to measure the participants' skill of seeing nature as a system (STS-2). The question asked to participants was "What does a tree and a lake mean to you"? While the researcher was analyzing essay writings, two themes (integral ecology, and human-nature relationship) and four categories related to integral ecology (identifying more than two, two, one and no aspects of integral ecology) and three categories related to human-nature relationship (holistic, mechanistic and no view) emerged according to coding booklet (Appendix-F).

The results revealed that six of the PSTs among eight were unable to describe nature as a system, yet two of the PSTs attempted to describe nature as a system. To be specific, two participants' STS level was found in the category of identifying two aspects of integral ecology. To put it differently, they described nature in terms of technical point of view such as trees as source of oxygen or source of wood (*behavioral aspect of integral ecology*) and in terms of subjective perspective such as trees as source of joy and beauty (*experience aspect of integral ecology*). These two participants also held the category of *holistic view* based on the theme of human-nature relationship. That is, they referred to human-nature relationship through a simple holistic view; for instance, they wrote that trees were source of oxygen, wood, food, joy and beauty and human life depends on them. Therefore, these participants' level of system thinking skill for seeing nature as a system was evaluated in the *developing* based on the rubric
(Appendix E).

On the other hand, six participants out of eight were found in the category of *identifying one aspect of integral ecology*. That is to say, they explained nature in terms of technical point of view like trees as source of oxygen (behavioral aspect) or in terms of subjective perspective like trees as source of joy or proving shadow for us (Experience aspect). Moreover, they were in the category of *mechanistic view* based on the human-nature relationship theme. They described nature through a mechanistic perspective. In other words, human is separated from nature, and trees and lake exist for humanity.

Therefore, these participants' level of system thinking skill to see nature as a system was evaluated in the *emerging* level (Table 4.15).

Table 4.15

Initial States of the PSTs' STS -2: Essay Writing Results

Essay writing					
STS	Themes and Categories		PSTs	Sample Statements	STS Level
	1.Integral Ecology	**2.Human-Nature Relationship (HNR)**			
STS-2: Seeing Nature as a System	**1a.Identifying two aspects of integral ecology** **(**e.g., behavioral (source of oxygen, wood, food) and experience (source of joy, beauty))	**2a.Holistic view**	PST-1 PST-3	PST-1: A tree is an oxygen source for all living things, so it represents life. For a child, a tree means more social activities such as playing area, hanging his swing or climbing. It means a shadow for us. It means food, source of wood and source of joy. For me a tree is not only one thing. **Our life depends on trees.** Lakes are part of water cycle. Lake means life, future, health, and peace.	Developing
	1b.Identifying one aspect of integral ecology (e.g., behavioral (source of oxygen or experience (e.g., source of joy, beauty)	**2b.Mechanistic view**	PST-2 PST-4 PST-5 PST-6 PST-7 PST-8	PST-6: We can relax under the shadow of the trees and trees provide oxygen and food with us. Lakes provide a living environment for us.	Emerging

4.3.1.1.2 Initial state of STS measured through Case Study Analysis-I

Case study analysis was used to test the system thinking skills to identify aspects of sustainability (STS-1), identifying components of a system (STS-3) and analyzing interconnections among the aspects sustainability (STS-4). The participants were asked to evaluate the case given with the title “We are losing our pastures” which was related to deterioration of the pastures and ecosystems because of the airport construction and its possible consequences on the environment, people’s lives and economy (Appendix B).

According to the data analysis scheme (Table 3.8) the defined theme to identify aspects of sustainability (STS-1) was aspects of sustainability and four related categories were identifying all, two, one and no aspects of sustainability. To identify components of a system (STS-3), the defined theme was components of a system, and the categories were multiple, single and no component. To analyze interconnections (STS-4), the theme was defined as interconnection among the aspects of sustainability, and the four categories were determined as interconnection among the all, two aspects of sustainability, separated explanation and no interconnection (Coding booklet-Appendix F).

Accordingly, the results revealed that three participants have the skills to resolve two aspects of sustainability (e.g., environmental, social), yet five participants struggled to identify more than one aspect of sustainability. In other words, three participants’ descriptions were found in the category of *identifying two aspects of sustainability* as they described the case as encompassing environmental, social and/or economic aspects of sustainability such as destruction of the natural environment and local people’s right to live. Therefore, their level of STS was evaluated as *developing.* Descriptions of five participants among eight, on the other hand, were found in the category of *identifying one aspect of sustainability.* That is to say, these participants described the case by referring to only environmental aspect of sustainability such as destruction of the nature or only social aspect of sustainability such as local people's right to live. Therefore, their level of the skill was found as *emerging.*

However, none of the participants described the case in terms of three aspects of sustainability (environmental, social, and economic).

Another result case study analysis revealed was that three participants among eight referred to multiple components while describing the case. Yet, five participants explained the case through one or two components. Accordingly, three participants' STS were found in the category of *multiple components* based on the *components of a system* theme. They described the case through such components as nature, people, airport construction, agriculture and economic production. Therefore, their level of STS for identifying components of a system was found as *developing.* On the other hand, five participants' STS were evaluated in the *single component* category since they described the case including one or two components such as people and nature. For this reason, their level of STS was defined as *emerging.*

Lastly, case study analysis results suggested that seven participants among eight could not analyze interconnections among the components. Only one participant's statement was found in the category of *interconnection among the two aspects of sustainability*. That is, she could analyze interconnections among environmental and economic aspects of sustainability. For example, she emphasized the balance between economy and environment in her explanation. Therefore, her STS level was assigned to *developing* level. On the other hand, descriptions of three participants were found in the category of *separated explanation* and four of the participants' descriptions were found in the category of *no interconnection.* That is to say, three participants struggled to analyze interconnections among the aspects of sustainability. For instance, instead of writing about how destruction of natural sources influence people's working and social life, they only described environmental and social components of the case without making a connection among them. Therefore, their STS level was determined as *emerging*. On the other hand, four participants could not refer to any particular interconnection; therefore, their level of STS was found in the *pre-aware* level. Above mentioned results are presented in the Table 4.16 in terms of themes, categories, STS levels and sample statements.

Table 4.16

Initial state of PSTs' STS: Results of the Case Study Analysis-I

Case Study Analysis-I				
STS	Themes and Categories	PSTs	Sample Statements	STS Level
STS-1: Identifying aspects of sustainability	**Aspects of Sustainability**			Developing
	a. Identifying two aspects of sustainability **(**e.g., environmental **(**destruction of natural habitat), social (local people right to live) or economical (balance between nature and development))	PST-1 PST-2 PST-3	PST-1: In this story, on one hand, there are nature, forest, lake, animals, farms that all life depend on and on the other hand, there are people who are forced to leave their lands and leave their jobs. If we could not stop this, we will suffer from its results because environmental sources are not limitless.	
	b. Identifying one aspect of sustainability (e.g., environmental (destruction of natural habitat) or social (local people right to live)).	PST-4 PST-5 PST-6 PST-7 PST-8	PST-5: This is not a new situation (*destruction of the environment because of airport construction in İstanbul*). Because of money and power challenges, we are destroying rights of people.	Emerging

Table 4.16 (Continued)

	Components of a system			
STS-3: Identifying components of a system	**a. Multiple Components** (e.g., nature, the impact of construction, local people’s life, economy, production, agriculture)	PST-1 PST-2 PST-3	PST-1: I felt so depressed while watching the video. How do people not see the consequences of this destruction? We see that there are nature, lake, forest, animals and farms there, and the city life depends on them. In addition, there are people living and working there, and they are forced to leave their land and quit their job. Destroying the nature is not a solution to build new places.	Developing
	b. Single Component (e.g., people and nature)	PST-4 PST-5 PST-6 PST-7 PST-8	PST-5: In this case, there are people who harm the environment and there are other people who are in a disadvantaged situation because of this destruction. There are also animals that will lose their habitat.	Emerging

Table 4.16 (Continued)

	Interconnection among the aspects of sustainability			
STS-4: Analyzing interconnections among the aspects sustainability	**a. Interconnection among the two aspects of sustainability** (e.g., development and environment)	PST-3	PST-3: We are producing, and we are building factories, but we don't care about nature. Yes we know it is difficult to live without technology, but we need to decrease this destruction. We can teach people the importance of natural life and environment and educate them to use their money for sustainable practices. Also, it is essential to improve living conditions of local people.	Developing
	b. Separated explanation	PST-1 PST-2 PST-4	PST-1: I felt so depressed while watching the video. How do people not see the consequences of this destruction *(environmental destruction because of airport construction in İstanbul)?* We see that there are nature, lakes, forest, animals and farms there and the city life depends on them. Moreover, there are people living and working there, and they are forced to leave their land and quit their job. Destroying the nature is not a solution to build new places.	Emerging
	No interconnection	PST-5 PST-6 PST-7 PST-8	PST-5: I wonder why the airport (*planned to be constructed in İstanbul*) has to be constructed in that area. In terms of sustainability perspective, they could build the airport to an infertile land in order to protect the natural balance.	Pre-aware

4.3.1.1.3 Initial state of STS measured through Interviews -I

Interview-I was conducted in order to measure eight systems thinking skills (STS-1 through STS-8), and interview questions were related to content of the Module-I) (Table 4.14). Each measurement tool has been prepared to measure specific STS. Twelve STS could not be measured in the interview-I since the interview questions were prepared based on the content of the Module-I. The questions in the interviews were related to essay writing and case study analysis. For example, in the first interviews participants were asked "What are the components of this case, and what could be the relationship among these components?"

The themes and categories were determined according to each specific systems thinking skill (Coding booklet-Appendix-F). While some skills (e.g., STS-2, STS-7) include detailed categorization, some of the skills were not evaluated based on the detailed categorization (e.g., STS-5, STS-6). This kind of categorization is related to nature and content of the skills. For instance, in terms of the skill of considering the relationship among past, present and future (STS-7), the theme was determined as making connections among past, present and future, and four categories were defined as making connection among three time spans, two time spans, considering two time spans simply and one time span. In order to measure STS-7 the question of "Could you give any examples related to this story? Does this story remind you any other place?" was asked to participants. Moreover, the theme for recognizing hidden dimensions (STS-5) was determined as hidden dimensions in a system, and two categories were defined as explaining and not explaining hidden dimensions. The question for STS-5, for example, was asked as "Do you think that there are any hidden dimensions in this case? If yes, what could be these dimensions?"

The results of the first interviews revealed that while three of the participants could refer to multiple aspects of sustainability (STS-1), five of the participants could not identify multiple aspects of sustainability. To be specific, three participants described sustainability as including environmental, social and sometimes economic aspects. For example, they defined sustainability as encompassing 3R (reduce, reuse and recycle), and they emphasized sustainability as reducing consumption and saving money. Therefore, the level of STS to identify the aspects of sustainability (STS-1) was determined as *developing.* On the other hand, five of the participants defined sustainability as including only environmental aspect such as recycling. Therefore, their level of STS was found as *emerging.*

The situation that sees nature as a system (STS-2) was found similar to the first skill. The results revealed that three participants among eight could describe nature as a system, yet five of them struggled to describe nature as a system. In other words, four participants described nature in terms of technical point of view like trees as source of oxygen (behavioral) and subjective point of view such as trees in their childhood memories (experience). They also described nature in terms of holistic view since they tried to describe nature as a living system. Therefore, four participants' level of STS was found as *developing.* On the other hand, other four participants among eight described nature from technical point of view (behavioral aspect) or subjective point of view such as remembering the trees in the picnic times (experience). Furthermore, they explained nature in terms of mechanistic view (mechanistic conception of nature) instead of describing nature as a living system. Therefore, their skill was assigned to *emerging* level.

Another skill explored in the first interviews was the skill of identifying components of a system (STS-3). Based on the results, four participants explained the case as including multiple components such as villagers, natural life, development, corporations etc. Specifically, they mentioned that villagers, trees, plants are all part of the land, but corporations are responsible for destroying nature and people's living areas. As they tried to explain multiple components related to case, their level of STS was found in the *developing* level. However, other four participants evaluated the case as including villagers and/or government, and they could not make a clear explanation about these components' role in the case. As they struggled to identify components related to case, their level of STS was found in the *emerging* level.

The situation for analyzing interconnections among the aspects of sustainability (STS-4) was different from the previous skill (STS-3). The results revealed that only one participant among eight could analyze interconnections among the two aspects of sustainability (e.g., environmental and economic). In her explanation she mentioned that there should be a balance between economic development and environmental protection. Therefore, her level of STS was found as *developing.* However, six participants struggled to analyze interconnection. Instead of explaining how social, environmental and economic aspects affect each other in the given case, they explained these aspects separately. Their level of STS was found as *emerging.* One participant on the other hand, could not make any particular interconnection and his level of STS was evaluated as *pre-aware* level.

The skill of recognizing hidden dimensions (STS-5) was measured in the first interviews. Based on the results, three participants among eight were able to explore hidden dimensions, yet five participants struggled to explain hidden dimensions related to case. That is, three participants explained several dimensions (e.g., the impact of climate change) that could not be seen at the first glance in the given case. For instance, in Table 4.18, PST-2 emphasized that people destroy the things that could store CO2 and they contribute to climate change. He made connection between people's lives and climate change. Therefore, their level of STS was evaluated as *developing.* Two participants tried to explain the impact of climate change, yet they could not make a meaningful connection between climate change and the given case. As they struggled to explain hidden dimensions, their level of STS was found in the *emerging* level. Other three participants, on the other hand, could not describe any hidden dimensions related to case. Therefore, their level of STS was found as *pre-aware.*

Another skill measured in the first interviews was recognizing own responsibility in the system (STS-6). The results showed that four of the participants' explanations were found in the category of *stating the own responsibility* based on the theme of *recognizing own responsibility in the system*. To be specific, they tried to make connection between the given case and their personal life. For instance, PST-8 made a connection between her travel habits and the problem in the given case which was about destruction of the natural land because of airport construction. As three participants tried to think about their personal choices, their level of STS was assigned to *developing* level. On the other hand, other four participants' explanations were found in the category of *not stating own responsibility*. They could not explain the relationship between the given case and their personal life. They blamed people in the system because of their irresponsibility. Therefore, their level of STS was found as *pre-aware.*

For the skill of considering the relationship between past, present and future (STS-7) five of the participants' explanations were found in the category of *considering two time spans simply* based on the theme of *considering the relationship among past, present and future.* They mentioned what happened in the past and what is happening at present related to given case; however, they could not make connection among these two time spans. As they had difficulty considering relationship between time spans, their level of STS was found as *emerging.* Three participants' explanations were found in the category of *considering one time span*. As three participants were unable to make connections among past, present and future, their skill was assigned to *pre-aware* level.

The last skill explored in the first interviews was developing empathy with people (STS-9). The results revealed that one participant's explanation was found in the category of *considering other people's perspectives in a simple way* based on the theme of *developing empathy with other people.* This participant tried to consider different stakeholders' (e.g., Villagers, young people) perspectives and develop empathy with them in the given case. Therefore, her level of STS was evaluated as *developing.* On the other hand, seven participants' explanations were found in the category of *considering other people's perspective in one side*. That is to say, these participants struggled to develop empathy with the stakeholders in the given case in a complete way. They mostly emphasized the impact of the problem on the villagers, yet they ignored other people's needs and perspectives in the case. For this reason, their empathy skill was evaluated as *emerging* (Table 4.17).

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Table 4.17

Initial state of PSTs' STS: Results of Interview-I

Interviews-I				
STS	Themes/Categories	PSTs	Sample Statements	STS Level
STS-1: Identifying aspects of sustainability	**Aspects of Sustainability** **a. Identifying two aspects of sustainability** (e.g., environmental such as recycling) and economic such as consumption)	PST-1,PST-2 PST-3	PST-1: Sustainability is related to cycling system and recycling of the natural resources. Sustainability is not only related to environment but also related to social life and economy. We are living in a consumption based society and when we have money, we just think about consumption.	Developing
	b. Identifying one aspect of sustainability (e.g., environmental such as recycling, composting etc.)	PST-4,PST-5 PST-6, PST-7 PST-8	PST-5: Sustainability is recycling for me. I think recycling is a sub-dimension of sustainability.	Emerging

Table 4.17 (Continued)

	1.Integral Ecology	**2.Human-Nature Relationship**			
STS-2: Seeing Nature as a System	**1a.Identifying two aspects of integral ecology** (e.g., behavioral -sources of oxygen and experience -childhood memories)	**2a.Holistic view** Explaining in a simple way	PST-1 PST-2 PST-3	PST-1: When we consider a group of trees, trees mean forest, many kinds of animals and habitat for these animals. Tree has multiple meanings. When we consider only one aspect, we don’t feel pain while cutting down the trees. I try to look at the whole picture. Lake also includes many species and provides a natural source for these species. It provides rain as well. Lake is a living thing and a lifeblood.	Developing
	1b.Identifying one aspect of integral ecology (e.g., experience-childhood memories or behavioral -source of oxygen)	**2b.Mechanistic View**	PST-4 PST-5 PST-6 PST-7 PST-8	PST-7: In my childhood, we were living in a village and we were going to picnic. At these times, I remember different types of fruit trees.	Emerging

Table 4.17 (Continued)

	Components of a system			
STS-3: Identifying components of a system	**a. Multiple Components** (e.g., villagers' right to live, development, natural life, social life, the impact of construction, corporations)	PST-1 PST-2 PST-3 PST-8	PST-2: The most important component in this case is the villagers. Villagers, trees, plants are all part of this place. Corporations must be responsible as they are building airports. They take away people's living right and destroy natural pastures.	Developing
	b. Single Component (e.g., villagers and government)	PST-4, PST-5 PST-6, PST-7	PST-4: There are government and villagers. I mean that there is one side who suffers and another side who gives harm.	Emerging
	Interconnection among the aspects of sustainability			
STS-4: Analyzing interconnectio ns among the aspects sustainability	**a. Interconnection among the two aspects of sustainability** (e.g.**,** economy and environment)	PST-3	PST-3: Yes, we need airports, but we need to build airports in a suitable way without harming nature. We need to do this by giving less harm to nature and people.	Developing
	b. Separated explanation	PST-1, PST-2 PST4, PST-6 PST-7, PST-8	PST-8: Instead of building a new airport, we could renew the old ones. We could improve public transportation system.	Emerging
	c. No interconnection	PST-5	PST-5: Instead of building airport there, it could be built in an infertile land in order to protect natural balance.	Pre-aware

Table 4.17 (Continued)

STS-5: Recognizing hidden dimensions	**Hidden Dimensions in a system**			
	a.Explaining hidden dimension(s) (e.g., climate change, globalization)	PST-1 PST-2 PST-8	PST-2: There are many hidden dimensions. For example, in an airport, many planes emit CO2 and contribute to climate change. In addition, we destroy the things that store CO2 and decrease the level of CO2 in the atmosphere such as trees.	Developing
	a.Explaining hidden dimension (e.g., climate change)	PST-3 PST-6	PST-6: There are trees and many species living there. Cutting down the trees contribute to climate change and causes disappearance of the species.	Emerging
	b.Not explaining hidden dimensions	PST-4 PST-5 PST-7	PST-7: This case is not related to nature. This problem is related to people living there. We did not learn anything about drought or vanishing of the species. This is not related to global issues.	Pre-aware
STS-6 : Recognizing own responsibility in the system	**Recognizing own responsibility**			
	a.Stating own responsibility	PST-1 PST-2 PST-3 PST-8	PST-8: I sometimes travel by plane. I thought that people had to leave their land and had to quit their job when the current airport was built. I was not thinking about these before when I was traveling but now, I am thinking more about this. I have a broader view.	Developing
	b.Not stating own responsibility	PST-4 PST-5 PST-6 PST-7	PST-6: There are these kinds of problems everywhere in Turkey. This problem in the case could happen to me, too. There is a connection like that.	Pre-aware

Table 4.17 (Continued)

	Making connection among the past, present and future			
STS-7: Consider the relationship between past, present and future	**a. Considering two time spans simply**	PST-1 PST-2 PST-3 PST-6 PST-8	PST-2: I remember my mother's village. There were more people, animals and more natural products. Now, there is nothing left. Now, there are not people, animals and there was not a production. There are only few people, and they do not deal with agriculture and animal farming.	Emerging
	b.Considering one time span	PST-4 PST-5 PST-7	PST-5: In the past, there was a road construction issue at METU. They were not only cutting down the trees but also they were destroying the forest.	Pre-aware
	Empathy with people			
STS-9: Developing empathy with other human beings	**a.Considering other people's perspectives in a simple way**	PST-4	PST-4: I thought about the trucks which were filling the lake with the soil, and I thought about the workers who use these trucks. I wonder whether they were aware of what they were doing. There are also young people who do not want to live in the village and want to move to cities. Villagers who earn their life in this land have to leave their land, so what will they do after that? This is sad. Nobody thinks about them.	Developing
	b.Considering other people's perspective in one side	PST-1, PST-2, PST-3, PST-5, PST-6, PST-7, PST-8	PST-7: There are people and species living there. These people earn their life in this land, and their farms and their land will be destroyed to make more profit.	Emerging

4.3.1.1.4 Summary-Determining the Initial State of STS

Initial state of systems thinking skills of PSTs was determined through three instruments (essay writing, case study analysis, interviews), and the results obtained from the three instruments allowed methodological triangulation to increase the credibility and validity of the results. Thus, triangulation enabled the researcher to explain the richness and complexity of human behavior more thoroughly by studying it from more than one standpoint (Cohen and Manion, 2000) and to search for regularities in the research data through cross-checking from multiple sources (O'Donoghue and Punch, 2003). The reason for this was that essay writing and case study analysis gave similar results with the interviews, and interviews provided rich amount of data.

Accordingly, results indicated that PSTs' STS levels were found as either emerging or developing to identify the aspects of sustainability (STS-1), seeing nature as a system (STS-2) and to identify the components of a system (STS-3). However, according to results, the skills went back to pre-aware level after STS-3. Six of the participants' skill of analyzing interconnections (STS-4), for example, was found at the low level (emerging). One participant, on the other hand, was found in the developing level which means that she was capable of analyzing interconnections among the aspects of sustainability in a simple way (Table 4.18). Similar to the first STS, the skill of developing empathy with people (STS-9) was found as either emerging or developing. It was also an expected result that none of the participants' level of STS was found as mastery. Moreover, pre-aware level was mostly found in the skills of STS-5, STS-6, STS-7 (Table 4.19). That is to say, some participants do not have any background related to these skills. It is understood that there are differences in STS levels from participant to participant.

Furthermore, the results revealed that there could be a complexity and hierarchy among the skills since the lowest STS level (pre-aware) emerged after three skills. However, this complexity may not be parallel with each participant's STS levels.

For example, although one person's STS-1 could be in the emerging level, the same person's STS-5 could be in the developing level. That is, it won't be unexpected to see a person going back and forward between STS as the course proceeds.

4.3.1.2 Developing STS: Module II and Module-III

STS development of the PSTs had been realized through the second and third modules of the course defined as *what is sustainable use of a system?* and *Sustainability Solutions respectively*. The modules were designed to answer the research question related to "How PSTs' systems thinking skills could be developed through the outdoor based ESD course" (Table 4.14). The Module II lasted five weeks, three weeks of which were held in the Lake Eymir exploring ecosystems, water quality and human use. The instruments used for collecting data on the STS of the PSTs were the field trip reports (I, II, III) for ecosystems, water quality and human use, interviews (Interview II) and accompanying concept maps which were obtained during the interviews.
The module III however, lasted four weeks, two weeks of which was held in the faculty backyard making compost and using it to design and create a vegetable garden. The instruments used to measure STSs for this module were field trip report (IV) related to composting and gardening, case study analysis-II and interview III with accompanying concept map (Table 4.13).

4.3.1.2.1 Developing STS through Module-II

STSs measured through three field reports (I-II-III) and an interview with accompanying concept map are presented in Table 4.18

Table 4.18

STS Measurement-Module-II

	Field Trip Reports	Interviews-II	Concept Maps-I
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 between past, present and future	√	√	
STS-8 Recognizing cyclic nature of the system		√	√
STS-9- Developing empathy with other human beings	√	√	
STS-10 Developing empathy with non-human beings		√	
STS-11 Developing sense of place		√	
STS-12 Adapting Systems thinking perspective to personal life		√	

4.3.1.2.1.1 Developing STS: Results of the Field Trip Reports (I-II-III)

Through the five weeks of the Module II, as titled as Sustainable use of Lake Eymir", three outdoor and two indoor lectures had been implemented. Within this period of time PSTs completed three field reports related to ecosystem, water quality and human use in Lake Eymir. Data analysis of the reports were realized based on the categories and themes and rubric (Appendix E-F)

Accordingly, the results revealed that the skill related to identifying aspects of sustainability (STS-1) has been developed. As displayed in Table 4.21 participants emphasized that Eymir has social, environmental and economic values. For example, PST-1 suggested that that it is possible to use Eymir for several activities without harming its environment. While two participants' STS level was found as *mastery*, two participants' STS level was evaluated as *developing*.

Similarly, the participants' systems thinking skill for seeing nature as a system (STS-2) has been improved during the course. That is to say, four participants among eight could see nature from a holistic view instead of mechanistic view (nature exist for humanity). PST-2 for instance, described Eymir as an interconnected system. For this reason, four participants' level of STS was assigned to *mastery* level.

Compared to the first two skills, it was revealed that more participants (six of them) developed their skill of identifying components (STS-3) through the five weeks of the course. After three field trips to Lake Eymir, they described Eymir from several perspectives (e.g., environmental, social, and economic). They also evaluated Eymir as a system including multiple components such as species in the lake, visitors, water quality parameters, restaurants etc.). Accordingly, three participants' level of STS was found as *mastery* and three of them were evaluated as *developing*.

According to results of the field reports, participants also developed their skill of analyzing interconnections (STS-4) in the course. The results revealed that participants started to evaluate interconnections among the aspects of sustainability. They evaluated the problems related Lake Eymir from both global and local perspectives. Two participants' level of STS was evaluated as *mastery* and three of them were evaluated as *developing.*

Unlike previous skills, the skill of recognizing hidden dimensions (STS-5) was developed for only one participant. As displayed in Table 4.21 PST-2 explained hidden dimensions related to sustainable use of Eymir in his report such as greenhouse effect, climate change, people life style. He also emphasized the reasons of climate change and its impacts on Eymir. Therefore, his level of STS was found as *mastery.*

According to analysis of the field reports, skill of recognizing own responsibility (STS-6) has been developed for six of the participants among eight. Six participants mentioned that it is important to feel part of the system and individual actions are also important to protect Lake Eymir. Specifically, based on the results four participants' level of STS were found as *mastery* and two participants' level of STS were found as *developing.*

Another skill explored in the field reports was the considering the relationship between past, present and future (STS-7). Similar to previous skills, five participants among eight developed their skill. One of the participants is able to make connection among three time spans (past, present, future). That is to say, she emphasized the relationship among the history, current use and the future of Eymir. Therefore, her level of STS was assigned to *master*y level. Other four participants are able to make connections between two time spans. Particularly, they realized that some actions happened in the history of Eymir have an impact on the current use of it. Therefore, their level of STS was found as *developing.*

The last skill measured in the field reports was developing empathy with other people (STS-9). The results indicated that four participants among eight developed their empathy skills through the five weeks of the course. To be specific, two participants are able to consider other people's perspective in a complete way and other two participants are able to consider other people's perspectives in a simple way. For instance, PST-7 put forward that workers in Eymir have economic concerns therefore; they try to protect Eymir's nature because their life depends on there. Especially, analysis of the third field report which is related to human uses in Eymir helped participants develop their empathy skills (*they made several interviews with people in Eymir*). Participants realized that people could have different perspectives, different thoughts and their reasons behind their actions could be different (Table 4.19).

Table 4.19

Developing STS though the Field Trip Reports (I-II-III)

Developing STS through Field Reports (I, II, III)				
STS	Themes /Categories	PSTs	Sample Statements	STS Levels
STS-I: Identifying aspects of sustainability	**Aspects of Sustainability** **a. Identifying all aspects of sustainability**	PST-1 PST-2	PST-1: In Eymir, there should be a system as carrying out human activities without destroying the environment. More people should be aware of Eymir. Therefore, we need to educate people so that they could feel part of the nature, and they could appreciate nature in Eymir. (Mastery)	Mastery
	b. Identifying two aspects of sustainability	PST-4 PST-7		Developing
STS-2: Seeing nature as a system	**1.Integral Ecology** / **2.Human Nature Relationship** **1a.Identifying more than two aspects** / **2b.Holistic view**	PST-1 PST-2 PST-7 PST-8	PST-1: We left behind three weeks, and I realized the value of the nature in Eymir, and I understood how nature is fragile. Analyzing water quality, for instance, helped me see that Lake Eymir has an interconnected system.	Mastery

Table 4.19 (Continued)

STS-3: Identifying components of a system	**Components of a system**			
	a.Multiple Components (e.g., species in the lake, visitors, restaurants)	PST-1,PST-2, PST-4	PST-2: We have to think about the whole picture, and we have to think globally. Greenhouse effect causes global warming, and global warming changes the climate which causes drought in Lake Eymir because of the increasing temperature. As a result this causes eutrophication and toxicity in the lake because people are using their own car instead of using public transportation. (STS-3/STS-4 Mastery)	Mastery
		PST-6,PST-7, PST-8		Developing
STS-4: Analyzing interconnections among the aspects sustainability	**Interconnection among the aspects of sustainability**	PST-1, PST-2		Mastery
	a. Interconnection among the all aspects of sustainability			
	b. Interconnection among the two aspects of sustainability	PST-4,PST-6, PST-8		Developing
STS-5: Recognizing hidden dimensions	**Hidden Dimensions in a system**	PST-2	PST-2: We don't act to stop climate change. We don't know, for example, eating one hamburger pollutes four tones of water. Greenhouse effect causes global warming, and it changes the climate, and this causes drought in Lake Eymir because of the increasing temperature and this causes eutrophication and toxicity in the lake.	Mastery
	a.Explaining hidden dimensions			

Table 4.19 (Continued)

STS-6: Recognizing own responsibility	**Recognizing own responsibility**			
	a.Stating the own responsibility	PST-1, PST-2, PST-3, PST-8	PST-3: I don't have a garden to grow vegetables. I only consume, and I feel happy when I go shopping. This makes me sad because I contribute to climate change, and in this way I have an influence on the future of Eymir (Mastery)	Mastery
		PST-6, PST-7		Developing
STS-7: Considering the relationship between past, present and future	**Making connection among past-present and future**		PST-1: The history of Eymir shows us how fragile the ecosystem in Eymir is. Today, we discuss about how to use Eymir in a sustainable way. If we believe that Eymir will be like this in the future, we can do something to protect it. In the past, we learnt that Eymir's nature was destroyed and rehabilitated again (Mastery).	
	a. Making connection among three time spans	PST-1		Mastery
	b.Considering two time spans	PST-4, PST-5, PST-6, PST-8		Developing
STS-9: Developing empathy with other people	**Empathy with people**		PST-7: I understand that people in Eymir are respectful to this place, and they make effort to protect Eymir's nature. For instance, one of the restaurant owners cares about the animals, trees in Eymir, and he is protecting the beauty of Eymir. I was very impressed by his thoughts. I also understood from the interviews that visitors do not care about Eymir unlike the workers. I see that people have different ideological perspectives and different thoughts	
	a.Considering other people's perspective in a complete way	PST-1, PST-7		Mastery
	b.Considering other people's perspectives in a simple way	PST-4, PST-8		Developing

4.3.1.2.1.2 Developing STS: Results of the Interview-II and Accompanying Concept Maps

4.3.1.2.1.2.1 Interview-II

Interview-II was conducted after the completion of field trips in the context of Module-II that coincides with five weeks of the course. As given in Table 4.18, the second interviews measured twelve systems thinking skills. The analysis were realized in line with the themes and categories set specifically for each STS presented in the coding booklet (Appendix-F) through constant comparative method and by the use of rubric developed by the researcher. For the skill of recognizing cyclic nature of the system (STS-8), for example, the theme was set as cycling nature of the system, and the two categories were defined as being able to explain/not explaining cycling nature of the system. Thus, the results of the analysis are presented through the themes and categories set specifically for each STS (Table 4.20).

According to the results of the second interviews, it is possible to reveal that the skill related to understanding sustainability (STS-1) has been developed for all the participants: Three of the eight participants were able to identify all aspects of sustainability. They explained sustainability as including social, environmental and economic aspects such as protection of the environment, happiness of people and economic development, and their level of STS was assigned to *mastery*. Five of them, however, were able to identify two aspects of sustainability. They described sustainability as encompassing recycling, reduction of the wastes and the impact of the linear system. Therefore, their level of STS was found as *developing.* No participants' level of STS was found as *pre-aware* and *emerging* (Table 4.20).

Similarly, the participants' STS to see nature as a system (STS-2) were also developed at the end of the five weeks of the course. As the results revealed, all of the participants developed their point of view related to the natural system. Furthermore, they reached to *mastery* level at the end of Module-II. All of the participants' STS were categorized as *identifying more than two aspects of integral ecology* and *holistic view* under the themes internal ecology and human-nature relationship respectively (Table 4.20). These participants described nature not only by technical point of view (behavior-trees as source of oxygen) and subjective point of view (experience-trees as source of beauty), but also they described nature as including many interactions (systems). Furthermore, they recognized that human was part of the nature and not playing a dominator role in nature (holistic view).

The situation for Identifying components of a system (STS-3) was found as similar to the first two skills. All the participants identified *multiple components* related to sustainable use of Eymir. They described many components related to environmental, social, economic values of Eymir such as human, forest, waste, natural system, population growth and climate change. Six of the participants in the *mastery* level had more detailed/complex explanations related to the components of a system compared to those found in the d*eveloping* level (Table 4.20).

Likewise, all the participants' skill for analyzing interconnections (STS-4) was found at *mastery* and *developing* levels at the end of the Module II. Four participants' skills were evaluated under the category of *Interconnection among the all aspects of sustainability*. They evaluated Lake Eymir in terms of social, environmental and economic aspects of sustainability and explained how these aspects impact each other. For instance, PST-1 stated that Eymir as an ecosystem was influenced by many factors such as urbanization and globalization (Table 4.20). Other four participants' skills, on the other hand, were evaluated under the *Interconnections among the two aspects of sustainability* category. For most of the time, they evaluated Lake Eymir in terms of social and environmental aspects and used economic aspects rarely. However, they frequently emphasized the impact of human use on the ecosystem of the lake.

The hidden dimensions related to sustainability of the Lake Eymir (STS-5) were reported as consumption, human lifestyle, globalization and climate change by the participants. Hence, their level of STS was evaluated as *mastery*. For those who only mentioned the impact of climate change on the lake; however, level of STS was defined as *developing*.

As the results revealed, all of the participants developed their systems thinking skill for recognizing own responsibility (STS-6) holding *mastery* and *developing* levels. They were able to think about their own responsibility in the system. Six participants mentioned that they were part of the system, and they were aware that individual actions had an impact on the system.

Considering the system thinking skill for constructing the relationship among past-present and future (STS-7), three participants' level of STS were evaluated under the category of *making connection among three time spans*, and thus, they reached to *mastery* level. These participants suggested that a development happening in the past could influence the present and the future. For instance, they said that if people continue to use Eymir in an unsustainable way, we could see the results in the future. Five participants' level of STS, on the other hand, was evaluated under the category *considering two time spans* and *developing* level. They were able to evaluate the impacts of current development trends on the future such as the impact of today's actions on the future of Eymir.

Another skill measured in the second interviews was related to recognizing cycling nature of the system (STS-8). It was the first time that this skill was explored in the participants' responses. Based on the results, seven participants mentioned that natural systems work in cycles, yet unsustainable human uses and climate change affect the system. Based on the results, their level of STS was evaluated as *developing.* On the other hand, only one participant struggled to explain cycling nature of the system and her level of STS was found as *emerging*.

As being one of the skills that was not initially owned by the participants making empathy with other people (STS-9) was found as *developing* at the end of Module II. Five participants among eight developed their empathy skills. Their STS was evaluated under the category *considering other people's perspectives in a complete way* and as *mastery* level. To be specific, they were able to develop empathy with different stakeholders such as workers, visitors and students. For instance, PST-1 put forward that people working in Eymir could have economic concerns because they earn their life there. Yet, three participants' empathy skill was evaluated under the category of *considering other people's perspectives in one side*. As they were not able to develop empathy with different stakeholders, their level of STS was evaluated as *emerging.*

As the results displayed, three participants' level of STS were evaluated as considering non-human beings (STS-10) at the end of the Module II. These participants were able to develop empathy with non-human beings as they said that they felt connected to the nature (especially trees) during the field trips. Therefore, the level of their skill for empathy with non-human beings was evaluated as *developing*. Five participants' skills for empathy with non-human beings, on the other hand, were evaluated under the category of *no empathy.* They expressed how they felt in the nature during the field trips; however, they did not state their connection with non-human beings. Therefore, the level for their empathy skill was found as *pre-aware*.

The categories used in evaluating the skill for developing sense of place (STS-11) were multi-dimensional and single-dimensional. According to the results, six participants among eight were evaluated as having *multidimensional sense of place* since they defined the place (Eymir) from more holistic and multidimensional perspective. Participants expressed the place with its natural environment (biophysical dimension), the impact of place on their feelings (psychological) and sometimes they mentioned their childhood memories and how they felt connected to the community (socio-cultural). As these participants tried to express the place from multidimensional perspective, the level of their sense of place skill was found as *developing*. Two participants, on the other hand, were found as having single dimensional sense of place since they expressed the place regarding only the natural environment (biophysical dimension). Therefore, the level for their sense of place skill was evaluated as *emerging*.

One of the other skills that was explored for the first time in this study was related to adapting systems thinking perspective to personal life (STS-12). Based on the interview results, three participants' skill for adapting systems thinking perspective to personal life were evaluated under the category of *transformative actions for sustainability*. These participants mentioned that the course has broadened their perspective for their future projects about sustainability and they expressed about transformative, meaningful projects for sustainability such as a project about sustainable use of water. Therefore, the level for their adaptation skill was evaluated as *developing.* Five participants on the other hand, were found as holding *simple actions for sustainability*. That is to say, they mentioned simple actions for sustainability that they were doing or intended to do such as recycling, reducing waste and composting. Therefore, the level of their skill was defined as *emerging*

Table 4.20

Developing STS through the Results of the Interviews-II

Interviews-II				
STS	Themes / Categories	PSTs	Sample Statements	STS Level
	Aspects of Sustainability			
STS-I: Identifying aspects of sustainability	**a.Identifying all aspects of sustainability** (e.g., environmental (recycling, environmental protection), social (happiness of people) and economic(development)	PST-1,PST-2 PST-3	PST-3: I define sustainability as the state when both people and environment are in a peaceful situation. While development continues, environment is protected as well.	Mastery
	b.Identifying two aspects of sustainability (e.g., environmental (recycling, reduction of waste) and cycling system, human lifestyle.	PST-4,PST-5 PST-6,PST-7 PST-8	PST-7: Sustainability means recycling for me. We need to contribute to this cycling system because everything is connected to each other. All living things and non-living things are part of the sustainability, but we sometimes destroy this cycling system.	Developing

Table 4.20 (Continued)

	1.Integral Ecology	**2.Human-Nature Relationship (HNR)**			
STS-2: Seeing Nature as a System	**1a.Identifying more than two aspects of integral ecology (**e.g., behavioral (source of oxygen, and experience (source of beauty) and systems (interactions in nature)	**2b.Holistic view**	PST-1 PST-2 PST-3 PST-4 PST-5 PST-6 PST-7 PST-8	PST-3: My point of view about trees and lake has changed. At the beginning, I see trees as an oxygen source, source of beauty and green space but now, after Eymir trips, I understand that they are important for sustainability of the ecosystems. Trees are home to many species that we see in Eymir. I also understand how human activities affect nature.	Mastery

Table 4.20 (Continued)

STS-3:Identifying components of a system	**Components of a system** **a. Multiple Components** (e.g., human, forest, waste, natural system, population growth)	PST-1, PST-2, PST-3, PST-4, PST-7, PST-8	PST-1: Eymir is an evolving ecosystem. Many things affect Eymir's ecosystem such as urbanization, population growth and globalization. Our life style! We are living far away from nature. We don't know sustainable systems and we are thinking in a linear way. This is related to our working life and our economic system. Our actions increase our carbon footprint, and this causes climate change. (Mastery)	Mastery
		PST-5, PST-6		Developing
STS-4:Analyzing interconnections among the aspects sustainability	**Interconnections among the aspects of Sustainability** **a.Interconnection among the all aspects of sustainability**	PST-1, PST-2 PST-3, PST-8	PST-1: Eymir is an evolving ecosystem. Many things affect Eymir's ecosystem such as urbanization, population growth and globalization. Our life style! We are living far away from nature. We don't know sustainable systems, and we are thinking in a linear way. This is related to our working life and our economic system. Our actions increase our carbon footprint and this causes climate change. (Mastery)	Mastery
	b.Interconnection among the two aspects of sustainability	PST-4,PST-5, PST-6, PST-7		Developing

Table 4.20 (Continued)

STS-5: Recognizing hidden dimensions	**Hidden dimensions in a system**			
	a.Explaining hidden dimensions	PST-1, PST-2, PST-3	PST-1: I wrote balance in my concept map. I mean the balance between materialism and spiritualism. We lose this balance because of the globalization and capitalism. Materialism dominates our way of thinking. This shapes out actions and impacts social life. We could not build the balance, and we consume a lot. We buy new mobile phone, new computer etc.	Mastery
		PST-4, PST-5, PST-6, PST-7, PST-8	PST-6: We waste water. We pollute water, and we destroy the balance. The number of rainy days is decreasing. We cause climate change. We will see the impact of climate change more. There will be water shortage.	Developing
STS-6: Recognizing own responsibility	**Recognizing own Responsibility**			
	a.Stating the own responsibility	PST-1, PST-2, PST-3, PST-6, PST-7, PST-8	PST-7: I have my own responsibility for Eymir in terms of social, environmental and economic causes. I spend time, have fun with my friends in Eymir. I go there. The important thing is how we use Eymir. Of course, we will visit there. We will make an economic contribution to the restaurants in Eymir as well. We also have to protect the environment in Eymir. We can use Eymir without giving harm to the environment.	Mastery
		PST-4, PST-5	PST-5: I am a person who influences the system both negatively and positively. For example, I produce waste. This affects water, forest and the life of the species. If I manage my waste regularly, I could support the sustainable system.	Developing

Table 4.20 (Continued)

STS-7: Considering the relationship between past, present and future	**Making connections among past, present and future** **a. Making connections among three time spans (past-present-future)**	PST-1, PST-2, PST-7	PST-7: In the past, people could swim in Lake Eymir. There were swinging competitions, but not now. The lake is not good for swimming. We are polluting the lake. If we continue like this, we can lose the lake because climate change also influences the lake. We could protect Eymir, but this is not enough. Everybody should work for the environment.	Mastery
	b. Considering two time spans	PST-3, PST-4, PST-5, PST-6, PST-8	PST-8: I see that because of some regulations, the number of visitors has decreased in Eymir. That means that there is less human impact in Eymir. This could influence the future of Eymir positively, but we need to care about Eymir more.	Developing
STS-8: Recognizing cycling nature of the system	**Cyclic nature of the system** **a.Explaining cycling nature of the system**	PST-1, PST-2, PST-3, PST-5, PST-6, PST-7, PST-8	PST-2: Nature recycles. All the wastes in nature are recycled on their own. People can do this as well. Nature works in cycles.	Developing
		PST-4	PST-4: I did not think about the cycles, but now I have started to think whether there is a relationship or not.	Emerging

Table 4.20 (Continued)

STS-9: Developing empathy with other people	**Empathy with people**			
	a. Considering other people's perspectives in a complete way	PST-1, PST-2 PST-4, PST-7 PST-8	PST-1: I understood that we all have different perspectives. People working in Eymir have economic concerns. However, we see Eymir as a recreational place to visit. We monitor water quality and we observe ecosystem there. We don't have any economic concerns, but these people make a living there.	Mastery
	b.Considering other people's perspective in one side	PST-3, PST-5 PST-6	PST-3: We talked to a person in Eymir. He was trying to do something for Eymir. He had economic concerns.	Emerging
STS-10: Developing empathy with non-human beings	**Empathy with non-human beings**			
	a.Considering non-human beings	PST-2, PST-3 PST-8	PST-4: I started to think about trees more. I care about them. I feel connected to them.	Developing
	b.No empathy with non-human beings	PST-1, PST-4 PST-5, PST-6 PST-7	PST-6: We had a class outside. I feel good and more positive.	Pre-aware
STS-11: Developing sense of place	**Sense of place**			
	a.Multidimensional (e.g., biophysical, psychological or socio-cultural)	PST-1, PST-2 PST-3, PST-4 PST-7, PST-8	PST-2: My experiences in Eymir reminded me of my childhood experiences. I felt very good. When we went to Eymir, I always remembered my childhood. When we were climbing to the hill, I remembered many things. It was a good experience	Developing
	b.Single-dimensional (e.g., biophysical)	PST-5, PST-6	PST-6: This place is beautiful. We had breakfast near the water. We observed nature in the forest.	Emerging

Table 4.20 (Continued)

STS-12: Adapting Systems thinking perspective to personal life	**Personal actions for sustainability**			
	a. Transformative actions for sustainability	PST-1, PST-2, PST-3	PST-2: I can do a project about sustainable use of water in my village. That could be related to cleaning our waste water and using it again. This course broadened my perspective about my projects in my village.	Developing
	b. Simple actions for sustainability	PST-4, PST-5, PST-6, PST-7, PST-8	PST-7: I try to reduce my waste. I could do composting in my garden. I am thinking about that.	Emerging

4.3.1.2.1.2.2 Concept Map Results through Module-II

At the end of five weeks of the course, participants were asked to draw a concept map showing the components and relationships related to sustainable use of a natural system (Lake Eymir). Concept maps have been evaluated based on the three STS: Identifying components and connections in a system (STS-3), recognizing hidden dimensions (STS-5) and cycling nature of the system (STS-8) and concept map rubric prepared by the researcher (Appendix E). Participants' concept maps were evaluated based on the evaluation criteria in the rubric (mastery, developing and emerging). In order to analyze concept maps, the themes were determined according to three STS (STS-3, STS-5 and STS-8); the themes of number of components, connections, hidden dimensions and complexity. Table 4.21 displays two participants' concept map analysis based on the themes and rubric level.

Table 4.21

Two Participants' Concept Map Analysis Results (Module-II)

	Developing STS: Results of the Concept Maps through Module-II Themes					STS Level
	Components of the system	**Hidden Dimensions**	**# of Components**	**# of Connections**	**Complexity**	
PST-1	e.g., Eymir, water, human, animals, forest, population growth, borders, holistic thinking, moral values, education, linear thinking	e.g., values, linear thinking, population growth etc.	26	45	Yes, Non-hierarchical, cycling map	Mastery
PST-7	e.g., Eymir, social perspective, economical perspective, environmental perspective, cafe and restaurants etc.	e.g., Recreational area	14	14	Linear relationships. Needs to be developed	Developing

The results revealed that three participants' concept maps (based on three STS) were evaluated in the mastery level. These participants showed most of the components and connections related to the natural system (Eymir). Hidden dimensions such as climate change, urbanization, and globalization were observed in their maps as well. As they displayed cycling and complex relationships, the concept maps were in a non-hierarchical shape. To be specific, three participants' concept maps indicated that they have an understanding of every component of a system which is related to each other and these components have complex relationships in a system.
On the other hand, five participants' concept maps have been evaluated in the developing level. These participants indicated some components and connections and hidden dimensions related to Eymir as a natural system in their maps, yet they had difficulty in showing complex and cycling relationships.

Sample concept map analysis of one participant in mastery level (PST-1) and one participant in the developing level (PST-7) was displayed in Table 4.21. Concept map drawings are also given in Figure 4.5 and 4.6. According to Table 4.20 and Figure 4.5, PST-1 used 26 components and 45 connections in her concept map. She drew Eymir at the center of the map and displayed most of the components, connections and also hidden dimensions such as moral values, linear thinking, and education for sustainable development. She used components related to Eymir such as water, animals, human, social life, natural system, ecosystem and population growth. According to her map, these core components were linked to climate change, education, technology, globalization and urbanization. Briefly, PST-1 created a non-hierarchical and complex concept map. Briefly, she had high level systems thinking skills, so her concept map was assigned to *mastery* level.

On the other hand, PST-7 showed 14 components and 14 connections in her concept map. She also drew Eymir at the center of the concept map and connections among three aspects of sustainability (environmental, social and economic) related to Eymir as a natural system. She did not show complex and cycling relationships. Therefore, her concept map was evaluated as *developing.*

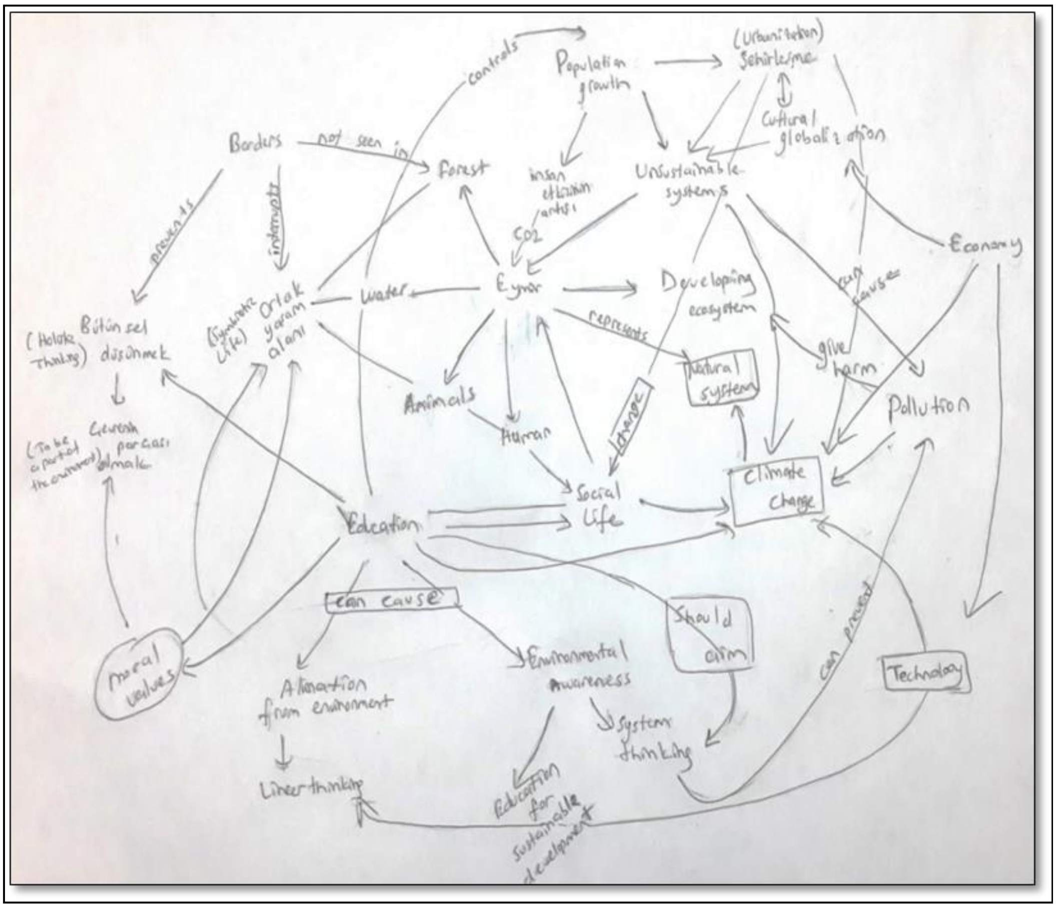

Figure 4.5 Concept map drawing through Module-II (PST-1)

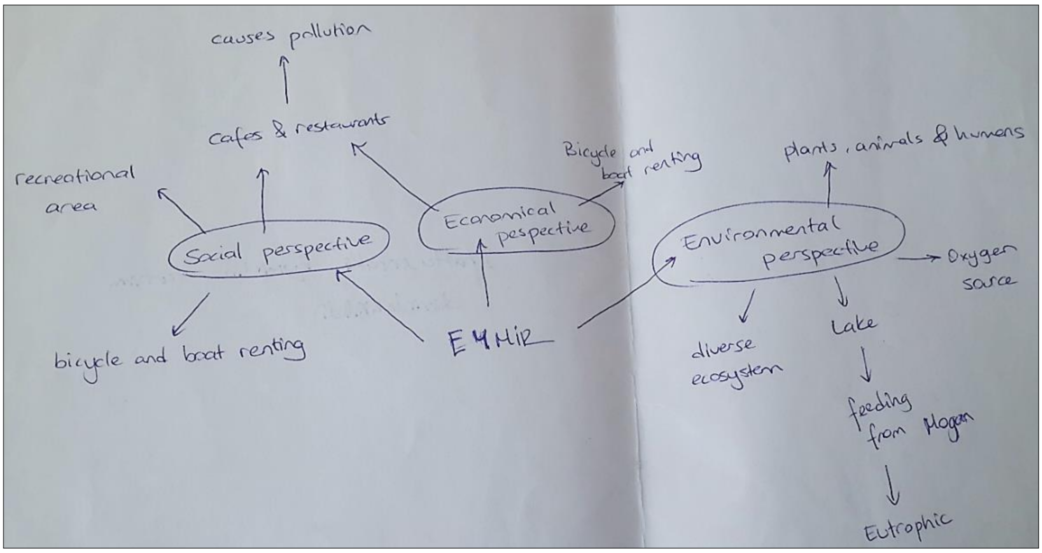

Figure 4.6 Concept Map drawing through Module II (PST-7)

4.3.1.2.1.2.3 Summary

PSTs' STS development during the five weeks of the course were evaluated through three instruments (Field Reports, Interviews and Concept Maps), and the results obtained from the three instruments allowed methodological triangulation to increase the credibility and validity of the results. In other words, field reports, interviews and concept maps gave similar results about STS development of PSTs.

PSTs' STS levels were found as either developing or mastery for identifying aspects of sustainability (STS-1), seeing nature as a system (STS-2), identifying components of a system (STS-3), analyzing interconnections (STS-4), recognizing hidden dimensions (STS-5), recognizing own responsibility (STS-6), considering the relationships among past, present and future (STS-7) and developing empathy with people (STS-9). Compared to initial state of STS, all of the participants developed their skills and none of these skills were found in the pre-aware and emerging level.

After the skill of STS-7, participants' STS were dispersed to all levels (pre-aware, emerging, developing and mastery). The skills of STS-8, STS-10, STS-11 and STS-12 were measured for the first time through the Module –II. At the end of the five weeks of the course, except one participant, all of the participants started to recognize that natural systems work in cycles (STS-8).

Yet, five of the participants among eight struggled to develop empathy with non-human beings, and they could not develop their skill (pre-aware). Only three participants could express how they felt connected to other species during the field trips, and their level of STS was defined as *developing.* Accordingly, it is revealed that developing empathy with non-human beings is one of the complex skills to be developed in a course.

The situation for the skill of sense of place (STS-11) was a little different from the previous skill. At the end of the Module-II, six participants developed their sense of place. These participants attributed multiple meanings (biophsyical, pscyhological etc.) to the place (Eymir). In other words, they were holding a multidisiciplinary lens to understand a place as a complex system.

However, there were two participants who struggled to define Eymir from multidisiciplinary lens, and their level of STS was defined as *emerging* at the end of the Module-II.

The last skill, adaptating systems thinking perspective to personal life (STS-12), was found as *emerging* and *developing* level. Only three participants mentioned that they had an intention to initiate transformative actions for sustainability. Other participants mostly mentioned simple actions for sustainability such as recycling and reducing waste.

These results indicated that field trips to Eymir contributed to development of STS levels of the participants. Furthermore, it was found out that there was a complexity and hierarchy among the STS. More specifically, low levels of STS (pre-aware and emerging) have been realized after STS-7. As complexity increased, low levels of STS emerged through the course.

4.3.1.2.2 Developing STS through Module-III

The third module of the course was defined as *Sustainability Solutions* in the context of composting and gardening. Participants explored how natural and human systems work together and how sustainability solutions could be produced. The Module-III lasted for four weeks. Two weeks of the course were held in the garden for planting and composting. The instruments used for collecting data on the STS of the PSTs were the field trip report (IV) for gardening and composting (Appendix D), case study analysis (II), interviews (Interview III) and accompanying concept maps which were obtained during the interviews. STS measured through field report, case study, interviews and concept maps are presented in Table 4.22.

Table 4.22

STS Measurement (Module-III)

	Field Trip Report-IV	Case Study Analysis-II	Interviews-III	Concept Maps-II
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 between past, present and future			√	
STS-8 Recognizing cyclic nature of the system	√		√	√
STS-9-Developing empathy with other human beings			√	
STS-10Developing empathy with non-human beings			√	
STS-11 Developing sense of place			√	
STS-12 Adapting Systems thinking perspective to personal life			√	

4.3.1.2.2.1 Developing STS: Results of the Field Report IV

Field Report-IV was related to finding solutions for sustainability in the context of gardening and composting. Accordingly, the results revealed that the skills related to recognizing own responsibility (STS-6) and recognizing cycling nature of the system (STS-8) had been developed through the Module-III. Gardening and composting activities helped participants understand cycling system in nature and their personal role in the system. As displayed in Table 4.23, participants explained that they play an important role to transform linear system to circular system by taking small actions such as reducing consumption, composting, recycling etc. Moreover, participants realized that all the natural systems work in cycles, and each component of a system is related to each other. Based on the participants' explanations, their STS levels were found as *mastery*.

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Table 4.23

Developing STS though the Field Trip Report-IV

Developing STS: Field Report-IV				
STS	Themes / Categories	PSTs	Sample Statements	STS Level
STS-6: Recognizing own responsibility in the system	**Recognizing own responsibility** **a.Stating the own responsibility**	PST-1,PST-2,PST-3,PST-4, PST-5,PST-6, PST-7, PST-8	PST-8: Nature works in cycles, but our mind works in a linear way, and this destroys everything. I need to think every time before acting. There are small things I can do to transform this linear system such as not using plastics and not consuming package food.	Mastery
STS-8: Recognizing cyclic nature of the system	**Cyclic nature of the system** **a.Explaining cycling nature of the system**	PST-1,PST-2,PST-3,PST-4, PST-5,PST-6, PST-7, PST-8	PST-5: Petrol based food system breaks the global natural cycles. While making compost, we could contribute to natural cycles and protect the balance among carbon, nitrogen and water cycles. Thus, we could contribute to sustainability. Therefore, it is not possible to separate composting, natural cycles and sustainability from each other. They are all related. If one of these components is affected in a negative way, others will also be affected.	Mastery

4.3.1.2.2.2 Developing STS: Results of the Case Study Analysis-II

The second case study analysis was conducted at the end of the course in order to test the system thinking skills to identify the aspects of sustainability (STS-1), to identify components of a system (STS-3) and analyze interconnections among the aspects sustainability (STS-4). The participants were asked to evaluate the case given with the title "The most expensive meat is consumed in Turkey" which was related to losing the fertile pastures and decreasing of animal farming and their impact on people's social and economic life (Appendix B-Case-II). Data analysis was based on the answers given to the questions asked related to the case.

Accordingly, the results revealed that all of the PSTs developed the skill related to identifying aspects of sustainability (STS-1). Specifically, seven of the participants could identify all aspects of sustainability. They evaluated the case from multiple perspectives. They especially focused on how economic concerns and development goals cause destruction in the environment and people's life. As displayed in Table 4.26, for example, PST-1 mentioned that insufficient policies influence agriculture and animal husbandry, and people living in the cities are influenced by its results. These participants' level of STS was evaluated as *mastery*.

Similarly, based on the case study analysis results, the participants' systems thinking skill for identifying components of a system (STS-3) was developed through the course. All of the participants evaluated the given case from multiple components such as agriculture, animal husbandry, urbanization, policy, ecosystem, farmers, unemployment etc. Six of the participants' level of STS was found as *mastery,* and one participant's level of STS was evaluated as *developing.*

The situation for the skill of analyzing interconnections (STS-4) was found similar to the first skills. All of the participants could analyze interconnections among the aspects of sustainability. Especially, six of them were able to evaluate the case by considering environmental, social and economic aspects. For instance, they mentioned that development goals of the government sometimes could have detrimental impacts on people's lives and environment as explained in the given case (e.g., decreasing of animal husbandry because of wrong policies) For this reason, their level of STS was evaluated as *mastery*.

Only one participant's level of STS was found as developing as he evaluated the case regarding two aspects of sustainability (social and economic) (Table 4.24)

Table 4.24

Developing STS through the Results of Case Study Analysis-II

Case Study Analysis-II				
STS	Themes / Categories	PSTs	Sample Statements	STS Level
STS-I: Identifying aspects of sustainability	**Aspects of Sustainability** **a.Identifying all aspects of sustainability** (environmental, economic, social)	PST-1, PST-2 PST-3, PST-5, PST-6, PST-7, PST-8	PST-1: The most important problem in this case is the decrease in the number of agricultural lands gradually. One of the results of this problem is that people are losing their connection with nature. Because of the wrong policies about agriculture and animal husbandry, the number of buildings in the cities is increasing, and this causes urbanization problem.	Mastery
STS-3: Identifying components of a system	**Components of a system** **a.Multiple Components** (e.g., agricultural lands, animal husbandry, urbanization, etc.)	PST-1, PST-2, PST-3, PST-6, PST-7, PST-8	PST-7: In this case, because of urbanization, agricultural lands are destroyed and animal husbandry is decreasing. When we lose agricultural lands, we have difficulty finding healthy food. Later, our dependency on other countries increasing. Our economy is affected, too.	Mastery
		PST-5	PST-5: This case is related to people’s unsustainable actions. Pastures used for animal husbandry are destroyed because of development goals.	Developing

Table 4.24 (Continued)

Case Study Analysis-II				
	Interconnection among the aspects of sustainability			
STS-4: Analyzing interconnections among the aspects sustainability	**a.Interconnection among the all aspects of sustainability** (social, economic, environmental)	PST-1, PST-2 PST-3,PST-6, PST-7, PST-8	PST-7: In this case, because of urbanization agricultural lands are destroyed and animal husbandry is decreasing. When we lose agricultural lands, we have difficulty finding healthy food. Later, our dependency on other countries increasing. Our economy is affected, too.	Mastery
	b.Interconnection among the two aspects of sustainability(e.g., social, economic)	PST-5	PST-5: These problems increase the number of unhappy people in the system. If people (e.g., farmers, workers) are not happy in a country, this will cause many more problems.	Developing

4.3.1.2.2.3 Developing STS: Results of the Interview-III and Accompanying Concept maps

4.3.1.2.2.3.1 Interview-III

Interview-III and accompanying concept maps were conducted at the end of the course after the completion of Module-III. The analysis was realized in line with the themes and categories set specifically for each STS presented in the coding booklet (Appendix-F) through constant comparative method and by the use of rubric developed by the researcher. The results of the analysis are presented through the themes and categories set specifically for each STS (Table 4.25).

According to results of the third interviews, all of the participants were able to identify aspects of sustainability (environmental, social and economic) at the end of the course. They described sustainability as encompassing multi-dimensions, thus, they developed a holistic view of sustainability. For instance, PST-6 said that at the beginning of the course, his sustainability definition was only based on the recycling, yet at the end, he realized that sustainability was more than recycling; that is, sustainability incorporates social, economic and environmental dimensions. In line with the participants' definitions, their level of STS was assigned to *mastery* level.

Likewise, all of the participants' skill of *Identifying components of a system* (STS-3) was found at *mastery* level. They determined multiple components related to given case and sustainability solutions in the context of gardening and composting. For instance, while they were analyzing the given case related to loss of the pastures and decrease in animal farming, they considered environmental, social and economic impacts of the problem together.

Similar to the first skills, participants' skill of analyzing interconnections among the aspects of sustainability (STS-4) was found at *mastery* level after the third module. To be specific, participants could not only define sustainability and its aspects, but they could also analyze interconnections among these aspects (social, economic and environmental). For instance, at the end of the course, they evaluated the given case by considering the impact of environmental destruction on people's social and economic lives. In other words, they talked about how destruction of the pastures influence animal farming, people's social and economic lives as well.

The hidden dimensions related to sustainability solutions (STS-5) were reported by all of participants as the impact of climate change on the environment and people's life. As they could recognize hidden dimensions in a system, their level of STS was evaluated as *mastery.*

Similarly, all of the participants developed their skill of *recognizing own responsibility in the system (STS-6).* They explained that they felt responsible for the choices they made in their life. In general, based on the interview results, participants recognized that they were part of a global system, and they have responsibilities for a sustainable future. Therefore, participants' level of STS was found as *mastery*.

Considering the system thinking skill for constructing a relationship among past-present and future (STS-7), six participants developed their skill to *mastery* level. These participants could make connections among three time spans (past, today and future). To be specific, they suggested that future events might be the results of the current actions and past developments. For instance, PST-4 emphasized that this course increased her ability to consider past, current and future state of the places (Table 4.28). On the other hand, two participants could make connections among two time spans (past and today); therefore, their level of STS was evaluated as *developing.*

Similar to the first skills, all of the participants developed their skill of *recognizing cyclic nature of the system (STS-8)* to *mastery* level. At the end of the module-III, they all realized that natural systems work in cycles and there is a connection among these cycles (water, nitrogen, carbon cycle). The results revealed that gardening and composting activities helped them understand cycling system in the nature in a comprehensive way. For instance, PST-1 noted that when she was planting a vegetable in the garden, she realized that we were all part of a big cycle.

Another skill explored in the third interviews was developing empathy with people (STS-9). At the end of the course, all of the participants stated that they could consider other people's perspectives. They could understand all the stakeholders' perspectives and their reasons behind their actions. They addressed the activities in the course such as case analysis, field trips were related to real life. Therefore, they could build more empathy with people. At the end of the course each participant's empathy skill was assigned to *mastery* level.

Unlike the skill of developing empathy with other people, not all of the participants developed their skill of developing empathy with non-human beings (STS-10) to *mastery* level. The results revealed that only one participant developed his skill to *mastery* level. He expressed his connection to all living things in the earth like every animal, every tree. Seven participants, on the other hand stated their connection to living things in a simple way and their level of STS was evaluated as *developing*.

Likewise, participants developed the skill of sense of place (STS-11) after the third module. According to results, especially field trips helped them feel more connection and responsibility to the places they visited. As five participants were able to build a multi-dimensional sense of place such as describing the places as natural and manmade environments (biophysical), socio-cultural factors and psychological factors, their level of STS was evaluated as *mastery*. Three participants' explanations contained two aspects such as psychological and biophysical meanings of the place; therefore, their level of STS was found as *developing*.

The last skill developed after the third module was adapting systems thinking perspective to personal life (STS-12). Interview results revealed that five participants started to adapt systems thinking perspective to their life by taking or intending to take transformative actions for sustainability. For instance, they mentioned that they had an intention to take personal actions for sustainability. They expressed that they were willing to create sustainability projects like supporting local products, increasing people's environmental awareness and initiating a gardening project. Therefore, five participants' level of STS was found as developing at the end of the course. Three participants among eight struggled to adapt systems thinking perspective to their personal life. That is to say, they described simple actions for sustainability such as recycling and reducing water consumptions instead of transformative actions. For this reason, three participants' level of STS was evaluated as *emerging.* Table 4.28 presents themes, categories, level of STS and sample statements.

Table 4.25

Developing STS through the Results of the Third Interviews (Module-III)

Interviews-III				
STS	Themes / Categories	PSTs	Sample Statements	STS Level
STS-I: Identifying aspects of sustainability	**Aspects of Sustainability** **a.Identifying all aspects of sustainability** (environmental, economic, social)	PST-1, PST-2 PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST6: Before this course, I was defining sustainability as recycling, but in this course, I realized that sustainability has other dimensions such as social and economic. I understood that everything is related to each other.	Mastery
STS-3: Identifying components of a system	**Components of a system** **a.Multiple Components** (people 'life, economic concerns, environmental and social concerns etc.)	PST-1, PST-2 PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-5: In the airport construction case, I only thought that the forest was destroyed, but now, I also consider people living there. I could see economic and social aspects of this case better. As an economic concern, for instance, the meat is imported and people feel unhappy because of this.	Mastery

Table 4.25 (Continued)

STS-4:Analyzing interconnections among the aspects sustainability	**Interconnection among the aspects of sustainability** **a.Interconnection among the all aspects of sustainability**	PST-1, PST-2, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-3: For instance, in the case people leave their land and move to the cities. This has economic consequences. People's social and economic life is influenced. In the cities, they earn less and their consumption habits change. While we are trying to develop, we are destroying our life.	Mastery
STS-5: Recognizing hidden dimensions	**Hidden Dimensions in a system** **a.Explaining hidden dimensions** (e.g., climate change, unemployment)	PST-1, PST-2, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-2: In the case, for instance, the impact of climate change was not mentioned. Airport construction will increase CO_2 concentration. The trucks working there contribute to climate change. Furthermore, unemployment increases in the cities and this causes the social problems.	Mastery
STS-6: Recognizing own responsibility in the system	**Recognizing own responsibility** **a.Stating own responsibility**	PST-1, PST-2, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-5: In this course I started to think more about my actions. I feel that we are all part of the system. I consider my responsibilities, and I realized my role in the system.	Mastery

Table 4.25 (Continued)

STS-7: Considering the relationship among past, present and future	**Making connection among past, present and future**	PST-1, PST-2, PST-3, PST-4, PST-7, PST-8	PST-4: For instance, we know the state of the Mamak landfill in the past, and we know its current state. If that place stayed like in the past, it would become bigger, and new areas of lands would be used, but now we can dream tomato fields in this place. I am thinking about that past, current and future state of the places.	Mastery
	a. Making connection among three time spans			
	b. Considering two time spans	PST-5, PST-6	PST-5: We are gaining experience. We do not want to have bad experiences that happened in the past; therefore, we know that we need to do something.	Developing
STS-8: Recognizing cyclic nature of the system	**Cyclic nature of the system**	PST-1, PST-2, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-1: We started to grow tomato and other plants. But this is not only about this. I see that all these things are part of a big cycle. I started to look at the big picture in this course.	Mastery
	a.Explaining cycling nature of the system			
STS-9: Developing empathy with other people	**Empathy with people**	PST-1, PST-2, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-7: I could understand the needs of the people mentioned in the case. They grow an animal, and they make a living. In Turkey, many people have these kinds of problems.	Mastery
	a.Considering other people's perspective in a complete way			

Table 4.25 (Continued)

STS-10: Developing empathy with non-human beings	**Empathy with non-human beings** **a.Considering non-human beings**	PST-2	PST-2: I feel that everything is connected to each other. We are connected to this table because we cut down the trees and contribute to climate change. I know that I am in a connection with all living things in the world, every animal, every tree etc.	Mastery
		PST-1, PST-3, PST-4, PST-5, PST-6, PST-7, PST-8	PST-7: I started to realize all the trees around me. I know that they exist.	Developing
STS-11: Developing sense of place	**Sense of place** **a.Multidimensional sense of place** (e.g., Biophysical, sociocultural, psychological)	PST-1, PST-2, PST-4, PST-7, PST-8	PST-2: When we visited Eymir, we met people working there. I felt more connected and responsible to Eymir. I realized how we influence nature. Eymir has a history. There were swimming competitions in the past in Eymir, but not now. We learnt that Eymir had water pollution problems in the past.	Mastery
		PST-3, PST-5, PST-6	PST-3: I felt myself more connected to the places. If I think more holistically, I could influence my students. When we decide something, we could consider environmental and social aspects. Therefore, I feel more connected to the places, nature.	Developing

Table 4.25 (Continued)

STS-12: Adapting Systems thinking perspective to personal life	**Personal actions for sustainability**			
	a.Transformative actions for sustainability	PST-1, PST-2, PST-3, PST-6, PST-8	PST-6: We are using industrial products instead of local products. Yet, when I become a teacher, I can make a garden to grow my own products or I prefer local markets for shopping. I can explain what sustainability is to my students and increase their awareness. We could take small steps like using local products and making compost.	Developing
	b. Simple actions for sustainability	PST-4, PST-5, PST-7	PST-4: I try to reduce my time in the bathroom. Using water unconsciously makes me uncomfortable. I am planning to make compost when I go to my village.	Emerging

4.3.1.2.2.3.2 Concept Map Results through Module-III

At the end of the course, participants were asked to draw a concept map showing the components and relationships related to Module-III (composting and gardening). As explained in the previous section, concept maps were evaluated based on three STS (STS-3, STS-5 and STS-8) and concept map rubric. In order to analyze concept maps, the themes of number of components, connections, hidden dimensions and complexity were used (Table 4.26).

The results revealed that while six participants' concept maps were evaluated in *mastery* level, two participants' concept maps were found in the *developing* level. None of the participants' concept maps were found in emerging level. That is to say, participants developed their STS of identifying components (STS-3), hidden dimensions (STS-5) and cycling nature of the system (STS-8) and created concept maps indicating more complex and cycling relationships among the components.

Table 4.26

Developing STS through the Results of the Concept Maps-II

Participants	Developing STS: Results of the Concept Maps through Module-III — Themes					STS Level
	Components of the system	**Hidden Dimensions**	**# of Components**	**# of Connections**	**Complexity**	
PST-4	Sustainability, sustainable farming, fair trade, green revolution, industrial agriculture, soil quality, biodiversity, cycle system, composting, food production, linear economy etc.	e.g., lifestyle choices	31	46	Non-hierarchical, cycling and complex	Mastery
PST-7	Composting, soil quality, organic food, life style choices, biodiversity, spiral garden etc.	e.g., lifestyle choices	13	14	Linear, hierarchical relationships, need to be developed	Developing

Data analysis results of sample concept maps in mastery and developing level are presented in Table 4.29. According to Table 4.26, PST-4 developed her concept map to *mastery* level at the end of the course. She used 31 components and 46 connections related to gardening and composting issues in Module-III. She incorporated sustainability at the center of her map and made connections among other concepts (e.g., sustainable farming, industrial agriculture, cycling system, climate change). Data analysis of her map revealed that she reflected most of the components and relationships related to the issue, used hidden dimensions, and thus, created a complex, cycling and non-hierarchical map at the end of the course (Figure 4.7).

On the other hand, PST-5 and PST-7's concept maps were assigned to developing level. As displayed in Table 4.26, for instance PST-7 used 13 components and 14 connections in her map. Even though she created a concept map incorporating more components and connections compared to the first one, her concept map included multiple linear, hierarchical relationships instead of complex, cycling relationships. Therefore, her concept map was evaluated as *developing* (Figure 4.8). Even though PST-5 and PST-7's STS (STS-3, 5 and 8) reached to mastery level based on the results of the third interviews, interestingly, their concept maps were found as developing at the end of the course.

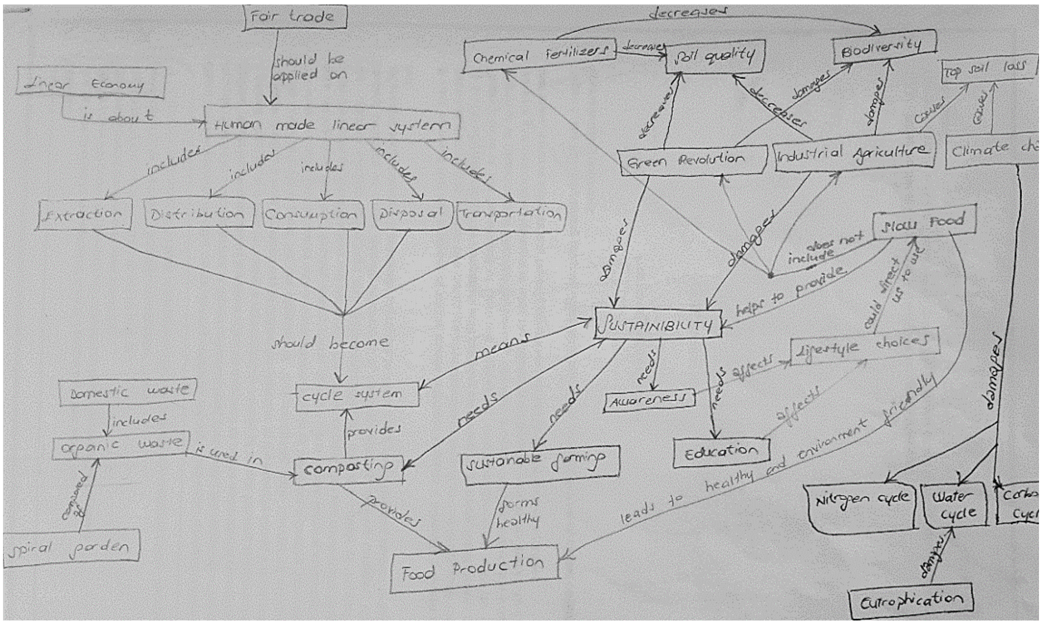

Figure 4.7 Concept Map Drawing through Module-III (PST-4)

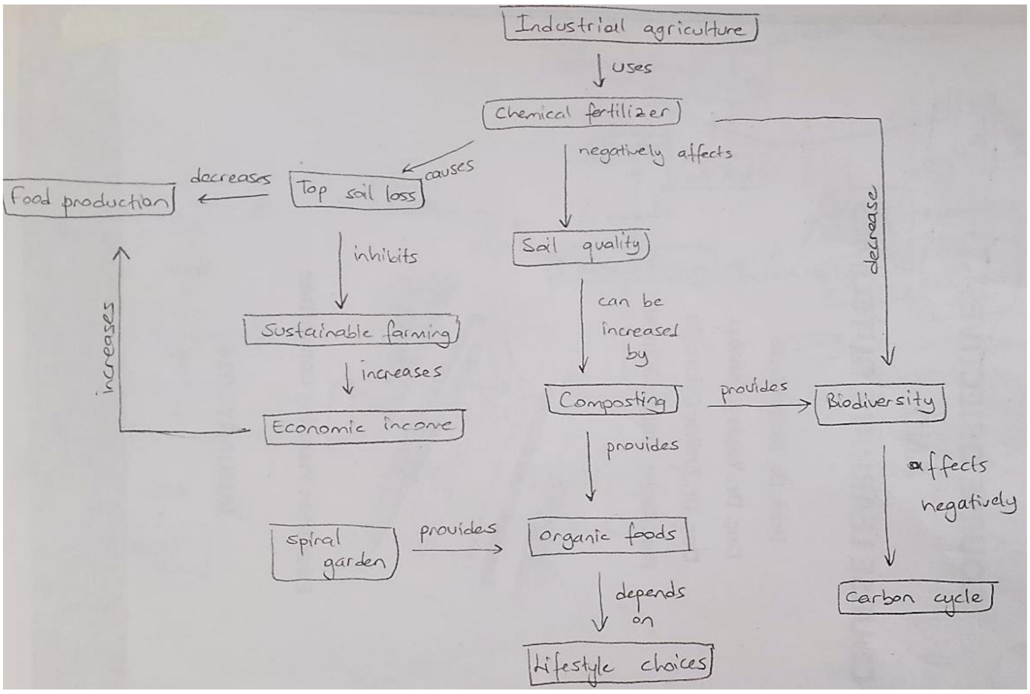

Figure 4.8 Concept Map drawing through Module-III (PST-7)

4.3.1.2.2.4 Summary-STS Development through Module-III

PSTs' STS development during the last five weeks of the course was evaluated through four instruments (Field Reports, Case Study Analysis, Interviews and Concept Maps). The results obtained from the four instruments allowed methodological triangulation to increase the credibility and validity of the results. In other words, field reports, case study analysis, interviews and concept maps provided similar results related to STS development of PSTs.

According to interview results participants' STS levels were found in either developing or mastery levels. Specifically, all of the participants' level of STS were evaluated as *mastery* for identifying aspects of sustainability (STS-1), seeing nature as a system (STS-2), identifying components of a system (STS-3), analyzing interconnections (STS-4), recognizing hidden dimensions (STS-5), recognizing own responsibility (STS-6), recognizing cycling nature of the system (STS-8) and developing empathy with people (STS-9). At the beginning of the course (Module-I) as predicted, none of the participants' level of STS were defined as *mastery*. Yet, the results indicated that participants developed their skills to the highest level (mastery) at the end of the Module-III. For instance, at the beginning of the course, participants could not identify all aspects of sustainability. They especially referred to environmental aspect of sustainability such as recycling and reducing waste. Furthermore, at the beginning they had difficulty identifying multiple components related to a system and analyze interconnections among these components (e.g., social, environmental and economic aspects). However, through the course participants showed an improvement on defining sustainability and its multiple aspects, identifying multiple components of a system and relationships among them. They defined sustainability as incorporating social, environmental and economic aspects and how these aspects are related to each other and affect the whole system together.

Moreover, the results unearthed that participants showed a gradual development at the end of the course for a number of STS (STS-7, STS-10, STS-11 and STS-12). That is to say, some participants could not reach to mastery level in those skills at the end of the course. It is understood that these skill are more complex compared to other skills, and it could be difficult to develop in a course.

Another interesting conclusion is that the third module which was related to "gardening and composting activities" especially contributed to developing participants' skills of recognizing own personal role in the system (STS-6) and understanding of the cycling nature of the system (STS-8). Furthermore, participants built a connection among these two skills. They explained that they could transform linear system created by people to cycling system through changing their personal actions. At the end of third module all of the participants developed these skills to *mastery* level.

Participants also improved other STS which are developing empathy with non-human beings (STS-10) and sense of place (STS-11) to *developing* and *mastery* level. However, at the end of the course there were still participants whose level of STS was found as developing for these two skills. For instance, only one participant whose level of STS was found as *mastery* since he emphasized how he felt connected to other living things at the end of the third module. Considering sense of place skill, five participants described a place as including multi-dimensional meaning for them at the end of the third module. That is to say, they developed complex, multidisciplinary perspectives for the places (e.g., Lake Eymir) during the course.

The last skill measured through the course was adapting systems thinking perspective to personal life (STS-12). According to results, it was revealed that this skill was the most complex one to develop at the end of the course. None of the participants' level of STS was found as *mastery.* Although some participants told about their intentions to take actions for sustainability, none of the participants said that they initiated transformative changes in their life for sustainability such as considering carbon footprint of the food or other things while shopping.

In general, the results yielded that all of the participants showed an increase in their STS levels at the end of the third module. As expected, none of the participants' STS levels were found in pre-aware level.

4.3.2 What extent do PSTs reflect systems thinking skills to instructional Planning under the light of the outdoor ESD course?

In order to reveal to what extent PSTs reflect systems thinking skills to instructional planning under the light of the outdoor ESD course, PSTs were asked to prepare a lesson plan at the end of the course. Lesson plans were evaluated in line with twelve STS and lesson plan rubric developed by the researcher (Appendix E).

The results revealed that PSTs reflected more than half of the STS in their lesson plans. As displayed in Table 4.30 regarding objectives and teaching procedure parts, three lesson plans were found in the exemplary level. That is to say, PSTs reflected more than two STS in their lesson plans such as identifying aspects of sustainability (STS-1), identifying components (STS-3), analyzing interconnections (STS-4) and recognizing own responsibility in the system (STS-6). Depending on the topic, participants emphasized different kinds of STS in the lesson plans. However, identifying sustainability aspects, identifying components, analyzing interconnections, recognizing hidden dimensions and recognizing own responsibility were the skills that were revealed most in the lesson plans.

Regarding objectives and teaching procedure parts, two lesson plans were found in the making progress level. That is, PSTs tried to integrate STS to their objectives and teaching activities; however, they sometimes could not reflect consistency between objectives and teaching activities. Based on the topic, they mostly emphasized the skills of identifying sustainability aspects, identifying components of a system and recognizing own responsibility.

As explored in the data analysis of the lesson plans, assessment was the most difficult part to integrate with STS. PSTs struggled to prepare an assessment tool to measure STS at the end of the lesson plan. Only PST-3's assessment part in the lesson plan was found in the exemplary level. She mentioned that she planned to ask students to draw a concept map showing the components and relationships related to topic which she planned to teach.

In general, as predicted, PSTs, whose level of STS were found as mastery or developing at the end of the outdoor ESD course, prepared lesson plans about incorporating a systems thinking perspective. To be specific, they planned to integrate aspects of sustainability into relevant topics, emphasize components and relationships in the system, human role in the system and also cycling nature of the system. Table 4.27 presents lesson plan analysis results of the participants.

Table 4.27

PSTs' Lesson Plan Analysis Results

Lesson Plan Analysis					
Participants	PST-1/PST-8	PST-2/ PST-6	PST-3	PST-4	PST-5/ PST-7
Topic	Ecosystem	Soil Erosion	Electricity	Recycling	Human Body Systems
STS reflected in the lesson plans	STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-8	STS-1, STS-3, STS-5, STS-6, STS-7	STS-1,STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-9 STS-11, STS-12	STS-1, STS-3, STS-6, STS-8	STS-1, STS-3, STS-4, STS-6, STS-8, STS-12
Objectives	Exemplary	Making Progress	Exemplary	Making Progress	Exemplary
Teaching Procedure	Exemplary	Making Progress	Exemplary	Making Progress	Exemplary
Assessment	Making Progress	Needs Development	Exemplary	Making Progress	Needs Development

4.3.2.1 Reflecting STS in the Lesson Plans (PST-1 and PST-8)

PST-1 and PST-8 prepared a lesson plan about ecosystem topic. The reason why they chose this topic was that they could easily integrate systems thinking perspective into this topic. Specifically, they focused on the elements of an ecosystem and interactions among them. In the objectives part, PST-1 and PST-8 included objectives related to identifying elements of an ecosystem (STS-3), explaining relationships (STS-4), and recognizing human impact in the ecosystems (STS-6). They also intended to give sustainability perspective while explaining human-nature relationship in their lesson plan. They incorporated sustainability, sustainable living, and system concepts in their lesson plan. In the teaching procedure, participants included activities which were consistent to the objectives. First, they planned to use discussion method. They planned to ask students the elements of an ecosystem, interactions among living and non-living components, and the question about how natural systems work (STS-2). Second, they intended to ask students to go outside and observe elements of an ecosystem and interactions among them. Later, they planned to ask students to create a concept map showing the elements and interactions in the ecosystem they observed. Thus, they planned to initiate a discussion environment about human impact on the ecosystems.

For the assessment part, participants planned to ask students to write an essay about the question of what is the effect of melting of glaciers as a result of human activities on the different kinds of ecosystems. They planned to measure several STS with one question, yet it is not certain which STS they intended to measure. Therefore, they need to develop assessment part of their lesson plan.

In summary, PST-1 and PST-8's lesson plans reflected systems thinking perspective. They integrated several STS into their lesson plan in order to develop students' skills. In the third interviews, participants were asked to explain how they prepared their lesson plan in order to get more detailed information. For instance, PST-1 stated that they planned to teach elements of an ecosystem, interactions and cycling nature of the system as presented in the vignette below:

> PST-1: We chose the topic of ecosystem because it is not possible to think any component of an ecosystem separated from each other. In the outdoor activity part, we planned to ask students to create a map including birds, trees. We intended to initiate a discussion environment by asking students the question of when we removed a tree from the system, what would happen? Thus, we planned to develop their understanding about cycling nature of the system. For example, when we remove the trees, this will affect the soil. When students observe this, they will understand the ecosystems better. We could develop a holistic understanding in that way.

Figure 4.9 presents summary of the lesson plan analysis of PST-1 and PST-8.

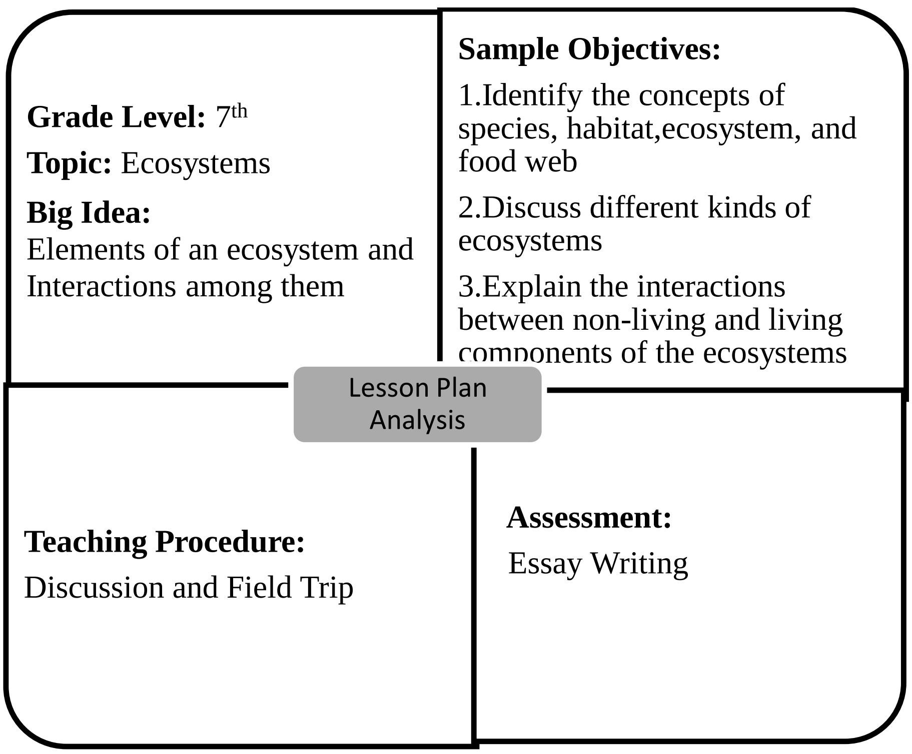

Figure 4.9 Summary of the lesson plan analysis (PST-1 and PST-8)

4.3.3 Overview

In this part, two research questions were investigated: 1. How can PSTs' systems thinking skills be developed through the outdoor based ESD course? and 2. To What extent do PSTs reflect their systems thinking skills to instructional planning under the light of the outdoor ESD course?

The first research question was answered through incorporating three modules (I-II-III) of the course while using a series of qualitative data gathering instruments (essay writing, interviews (I-II-III), case study analysis (I-II), concept maps and field reports). In Figure 4.10, each participant's developmental pattern is portrayed according to modules of the course (time). In terms of participants' initial level of STS and their STS development, two groups were identified. One group was defined as *participants who showed gradual development in STS* and the other group was defined as *participants who showed substantial progress in STS*.

Participants who showed gradual development in STS:

These participants' (PST-1, PST-2 and PST-3) starting point in STS was higher than other participants, and they showed a gradual increase in their skills to higher levels through the course. In other words, these three participants' initial levels of STS were found as emerging or developing, and during the course they developed their skills to developing or mastery level. Three participants' patterns especially in nine STS (STS-1 to STS-9) are consistent with each other. In the skills of identifying aspects of sustainability (STS-1), seeing nature as a system (STS-2), identifying components of a system (STS-3), recognizing hidden dimensions (STS-5), recognizing own responsibility in the system (STS-6) and recognizing cycling nature of the system (STS-8), participants developed their skills from developing to mastery level. In terms of the skills of analyzing interconnections among the aspects of sustainability (STS-4), considering the relationship between past, present and future (STS-7) and developing empathy with people (STS-9) while participants' initial level was emerging, and they developed their skills to mastery level.

On the other hand, in relation to skills of developing empathy with non-human beings (STS-10), sense of place (STS-11) and adapting systems thinking perspective to personal life (STS-12), participants' development patterns were different. For instance, PST-1's empathy skill with non-human beings was in the pre-aware level at the beginning of the course, she developed her skill to developing level at the end of the course, yet PST-2's initial level for empathy skill was evaluated as developing his skill stayed at the same level at the end of the course. Furthermore, participants improved their skills of sense of place and adapting systems thinking perspective to developing and mastery level.

For instance, PST-1 expressed how her view related to natural systems had changed during the field trips. At the beginning of the course, she simply described Lake Eymir from multiple perspectives like Eymir as a source of water, as a habitat for the species and as a living system. Therefore, her level of STS-2 was evaluated as developing. Nevertheless, through the course, she improved her perspective related to natural systems. In addition to above-mentioned characteristics, she described the importance of human-environment relationship in Lake Eymir. She explained that she understood how the life had changed in Eymir over time due to the human activities. Furthermore, she said that calculation of the amount of carbon in the trees expanded her view related to natural systems. She stated that she better understood how natural systems worked. Indeed, she developed her skill of seeing nature as a system through the course. PST-1, PST-2 and PST-3's STS development patterns according to weeks (2^{nd} week, 7^{th} week and 11^{th} week) are presented in the following figures (Figure 4.10).

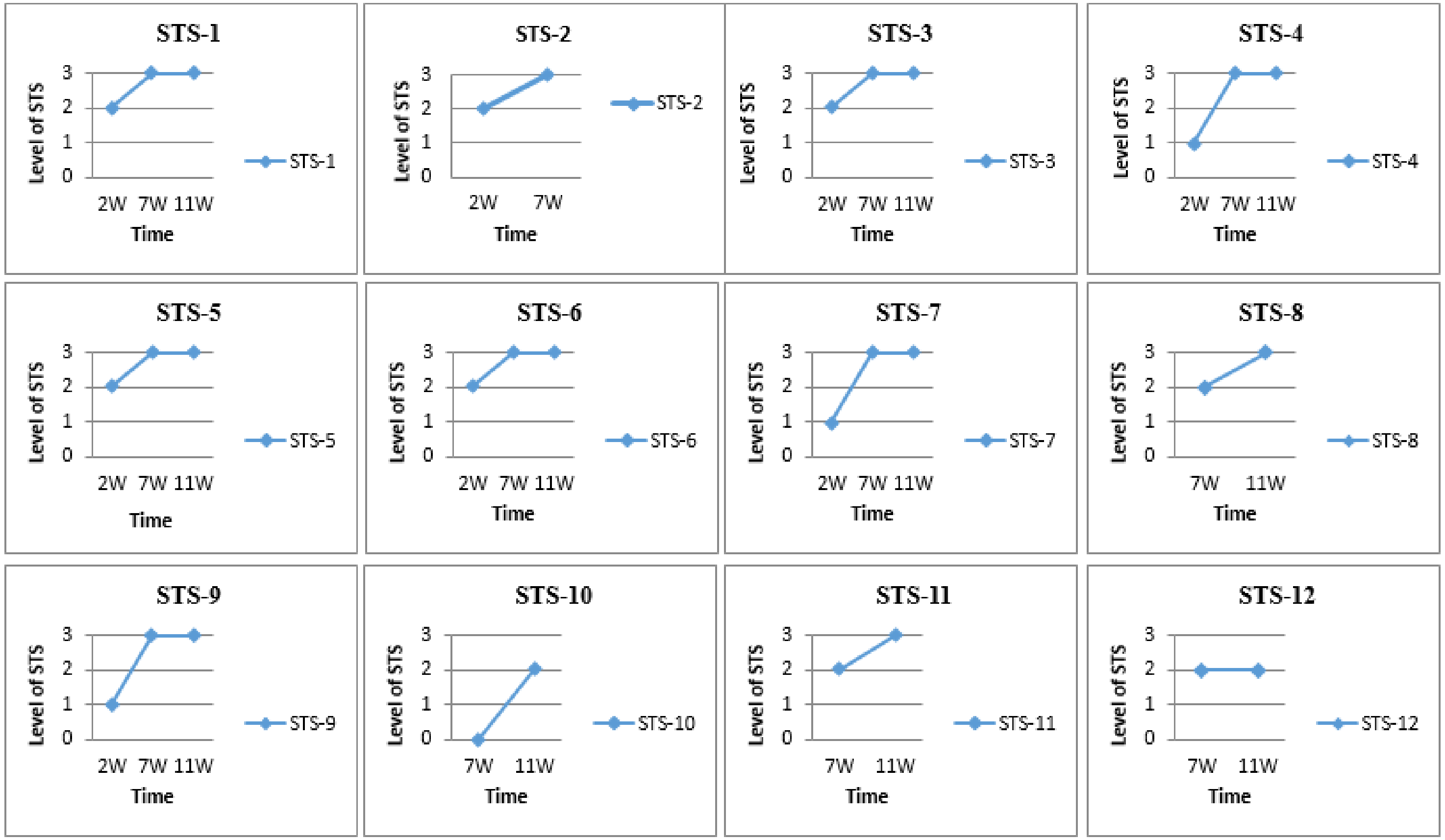

Figure 4.10 STS Development through the Course-PST-1 (3:Mastery, 2: Developing, 1:Emerging,0:Pre-aware)

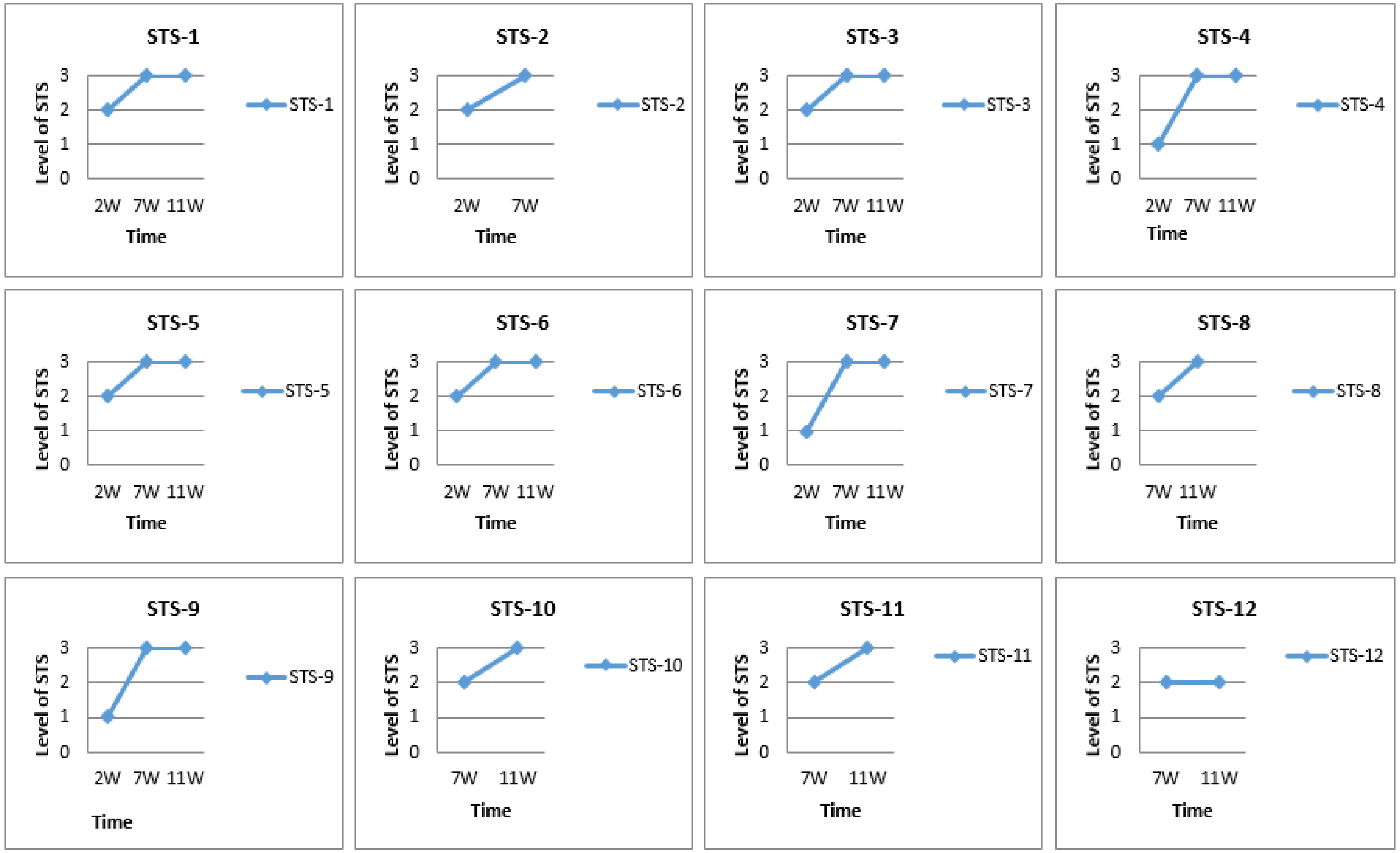

Figure 4.10 STS Development through the Course-PST-2

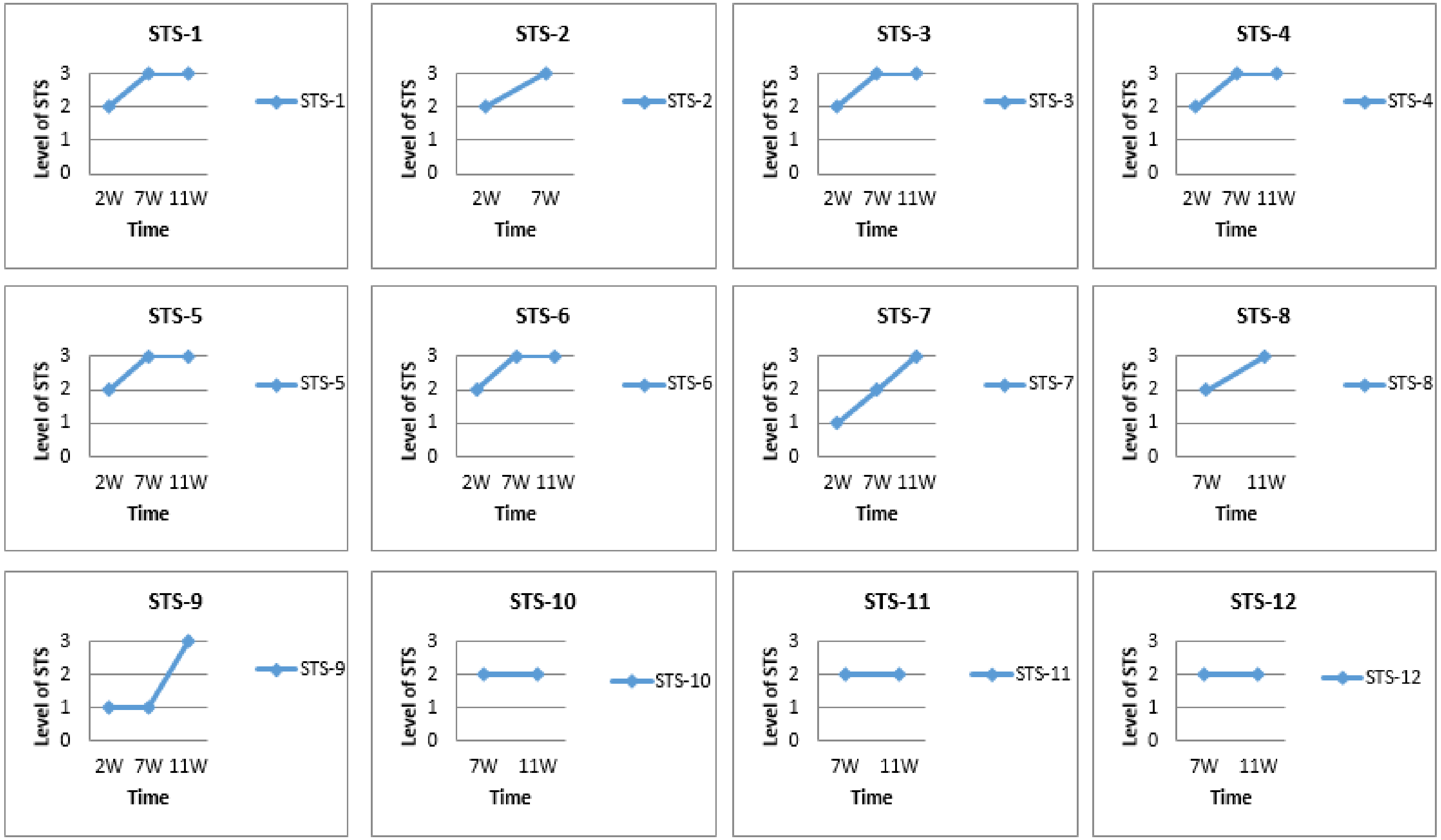

Figure 4.10 STS Development through the Course-PST-3

Participants who showed substantial progress in STS:

Although there are slight differences related to STS levels among five participants (PST-4, PST-5, PST-6, PST-7, PST-8), they were grouped as participants who showed a substantial development in the outdoor ESD course.

These participants' initial level of STS was usually found as emerging or pre-aware, and through the course they showed a substantial increase in their skills. To be specific, while participants' STS level was evaluated as pre-aware, at the end, they improved their skill to mastery level. For instance, five participants improved the skill of seeing nature as a system (STS-2) from emerging to mastery level; thus; they demonstrated a significant development in their skill. For example, in the second interview PST-6 said that his view about natural systems had changed and now he could recognize that everything is connected to each other and everything has a role in the ecosystems. He also said: "Now, I could understand that we need all these natural systems (e.g., lake and trees)".

Another example is that these five participants defined sustainability as including only environmental aspect at the beginning of the course (Table 4.17). For instance, PST-4 said that sustainability was related to recycling. However, at the end of the course, she defined sustainability in a more comprehensive way and she explained: "Sustainability means using natural resources by considering the next generations' needs". She also added: "We need to consider next generations, for example, people could use and benefit from Lake Eymir, but they need to protect it as well". She also explained that gardening and composting activities (Module-III) especially helped her understand natural systems work in cycle (STS-8). Moreover, it is evident in her concept map that she developed her STS (Figure 4.7). That is, she could identify multiple components and relationships related to gardening and composting issues. Furthermore, she put sustainability concept at the center of her map, and she showed connections among several dimensions (e.g., cycling system, sustainable farming) and sustainability.

In general, most of the participants improved their skills of STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-8 and STS-9 to mastery level. However, especially complex skills (STS-10, STS-11 and STS-12) stayed in the developing and emerging level at the end of the course. For instance, none of the participants developed their skill of adapting systems thinking perspective (STS-12) to mastery level.

They expressed their intention to take transformative actions for sustainability, yet some of them described taking simple actions (e.g., recycling) for sustainability.

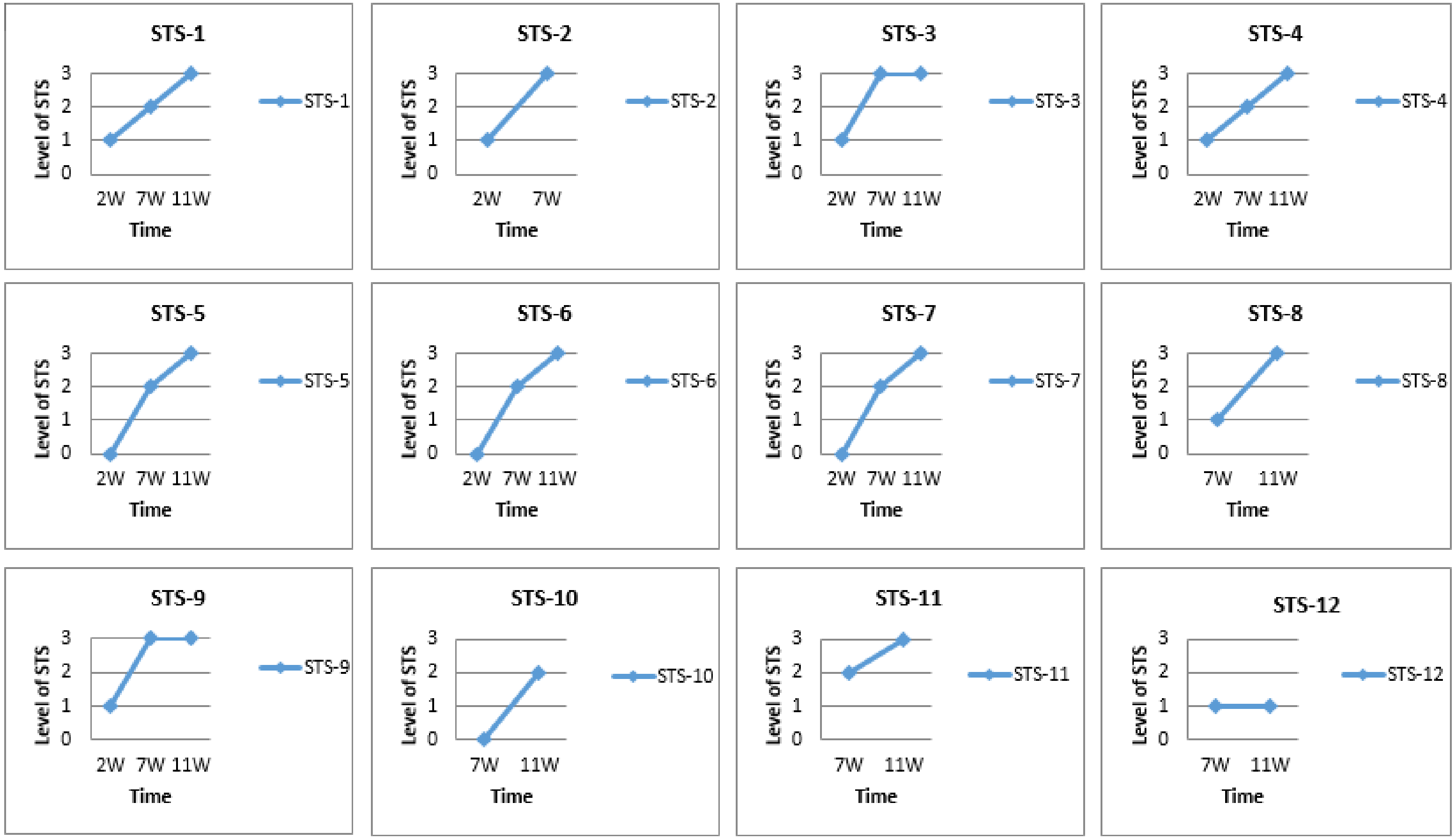

Figure 4.10 STS Development through the Course-PST-4

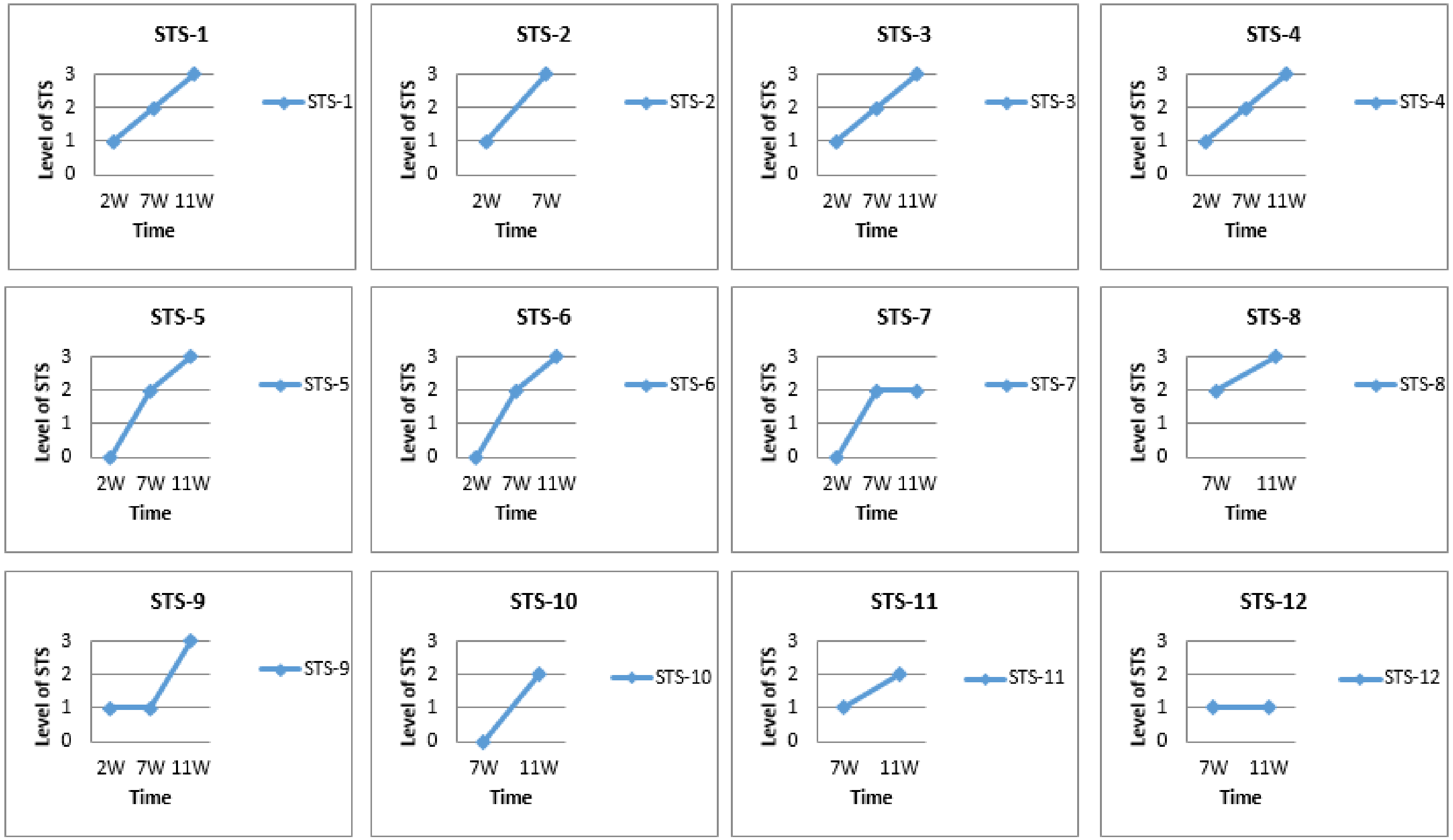

Figure 4.10 STS Development through the Course-PST-5

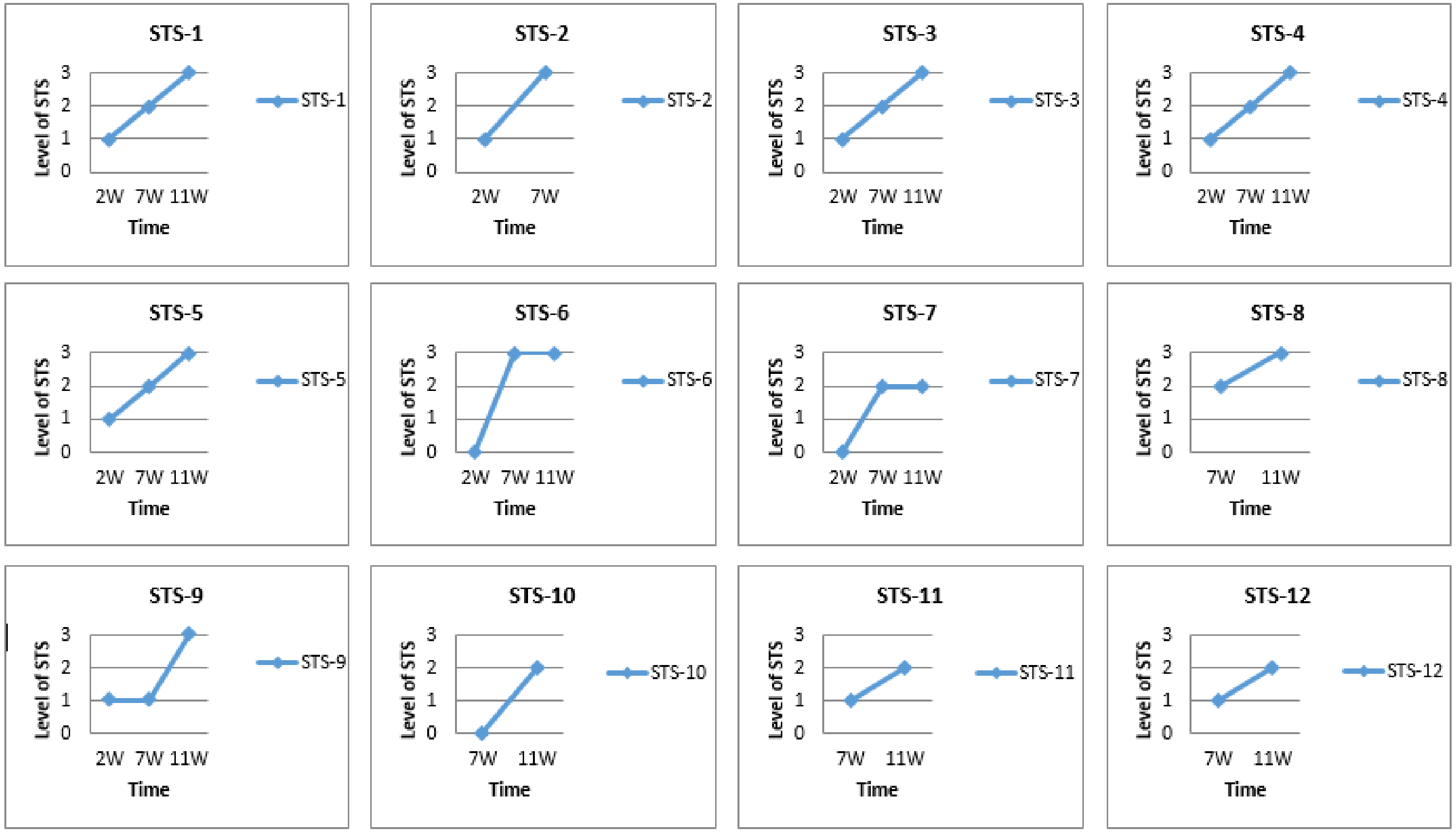

Figure 4.10 STS Development through the Course-PST-6

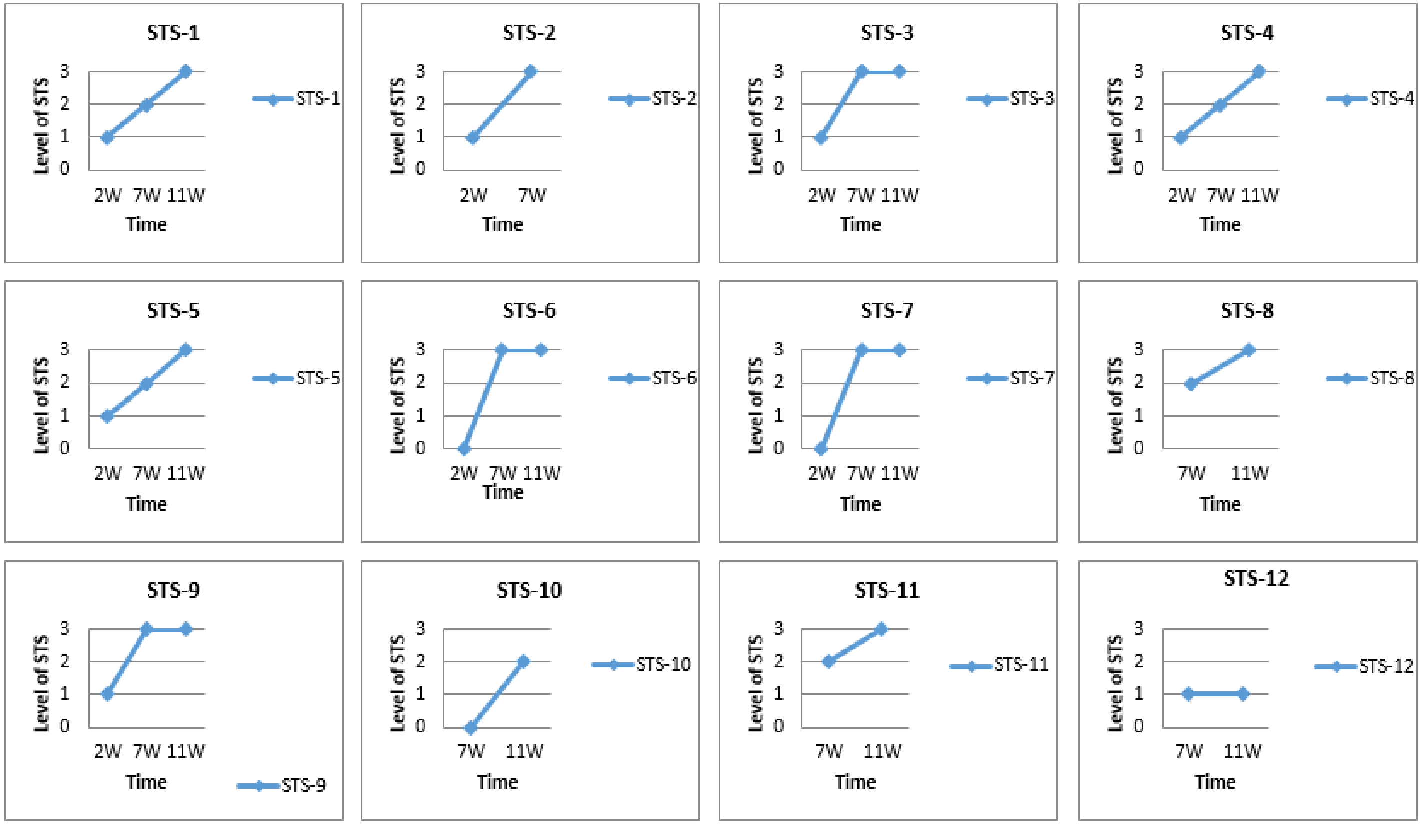

Figure 4.10 STS Development through the Course-PST-7

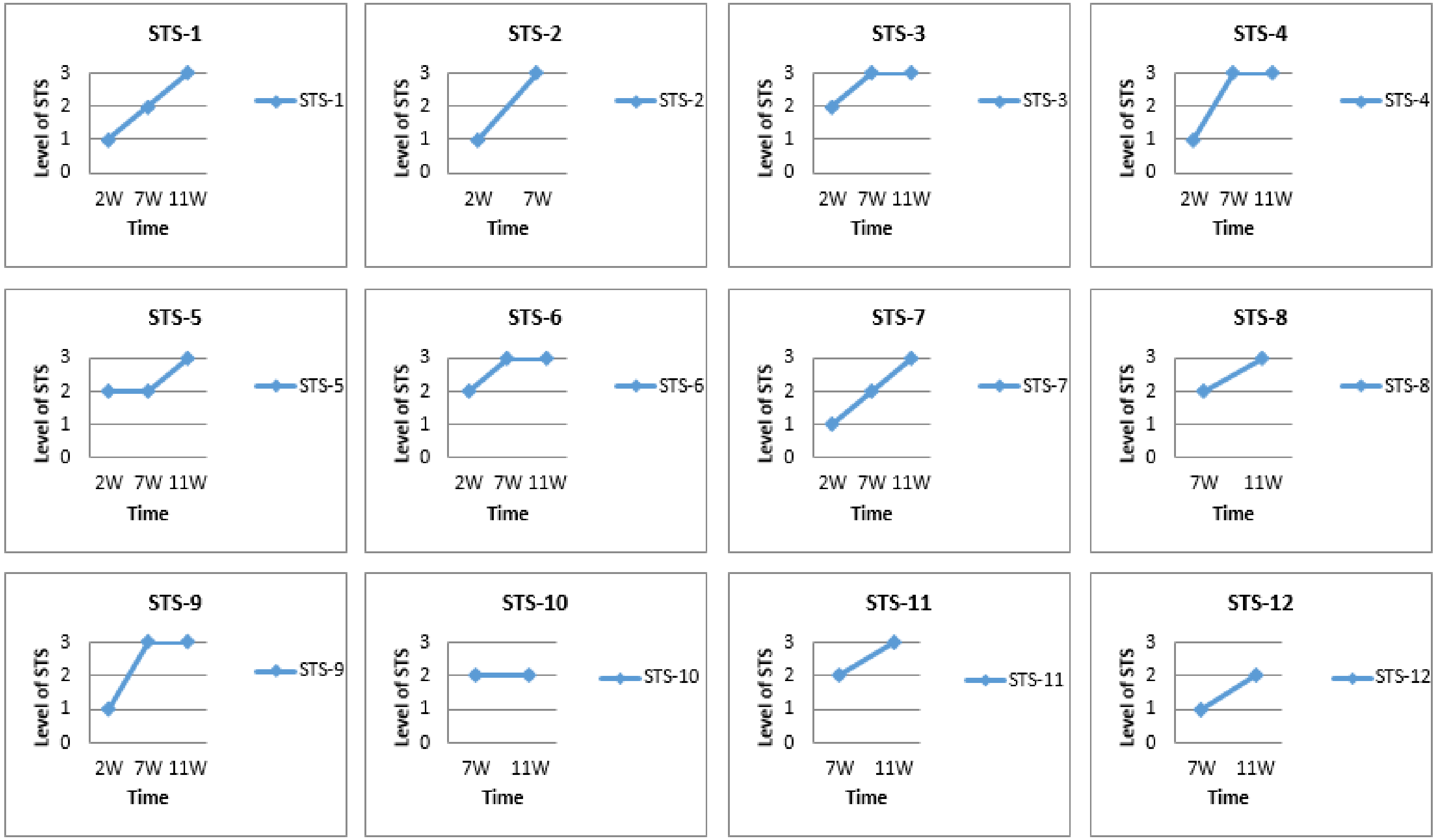

Figure 4.10 STS Development through the Course-PST-8

In summary, these results unearthed that there are individual differences in STS developmental pattern. In particular, participants whose initial STS level is higher than that of other participants showed a gradual increase in their skills. Yet, participants whose initial STS level is lower (pre-aware or emerging) than that of the other participants indicated a substantial progress in their skills.

Furthermore, it is revealed that there is a meaningful hierarchy among the skills and participants' STS development change in terms of complexity of the skills. Especially, most of the participants showed a slow improvement in the last skills (STS-10, STS-11 and STS-12). In other words, these skills are more complex than other skills.

Moreover, participants who could define aspects of sustainability (STS-1) could also identify components in a system (STS-3) and analyze interactions among these components (e.g., social, economic and environmental) (STS-4). If their level of STS-1 is found in the low level (emerging or pre-aware), it is difficult to reach to high level in STS-4 as STS-4 is more complex that STS-1 and STS-3. Nevertheless, the researcher does not claim that there is an accurate hierarchical relationship among twelve skills. As displayed in Figure 4.11, there could be four hierarchical levels based on the results. That is, STS-12 is the most complex skill indicated at the top level, and STS-10 and STS-11 are the second most complex skills. Furthermore, STS-4, STS-5, STS-6, STS-7, STS-8 and STS-9 could be defined as the third complex skills. Yet, it is not evident that there is a certain hierarchical level among these skills. For example, even though one person could develop empathy with human-beings (STS-9), he/she may not be able to recognize cycling nature of the system (STS-8). On the other hand, the simplest skills are identified as STS-1, STS-2 and STS-3 that could be developed easily through the course as shown in Figure 4.11.

Figure 4.12 also displays that there is a dispersion in the participants' STS developmental pattern from the basic skills to complex skills. In particular, all of the participants improved their skills (STS-1 to STS-9) to mastery level at the end of the course, yet participants' other skills (STS-10, STS-11 and STS-12) were found in various levels (emerging, developing and mastery).

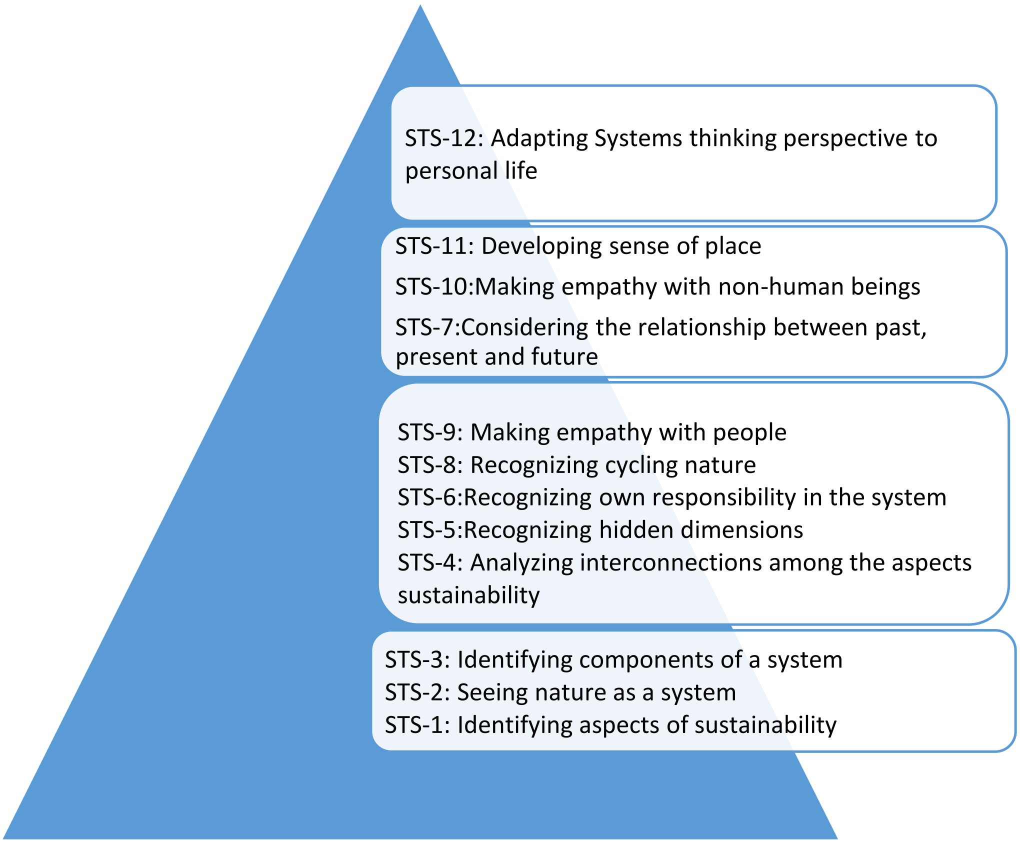

Figure 4.11 Systems Thinking Skills (STS)

Secondly, researcher investigated to what extent PSTs reflect their systems thinking skills to instructional planning under the light of the outdoor ESD course. In order to answer this research question, participants' lesson plans, prepared at the end of the semester, were analyzed. The results revealed that all of the participants explicitly reflected a number of STS in their lesson plans. As expected, participants intended to integrate the skills which they improved into the highest level at the end of the course such as identifying aspects of sustainability (STS-1) and identifying components of a system (STS-3). In the lesson plans, they mostly emphasized the skills of identifying components of a system (e.g, Ecosystem), hidden dimensions, relationships among the components (STS-5), integration to sustainability and understanding personal responsibility in a system. On the other hand, most of the participants were unable to address several complex skills which are develop empathy with non-human beings (STS-10), sense of place (STS-11) and adapting systems thinking to personal life (STS-11). Figure 4.12 presents all of the participants' STS development patterns through the outdoor ESD course.

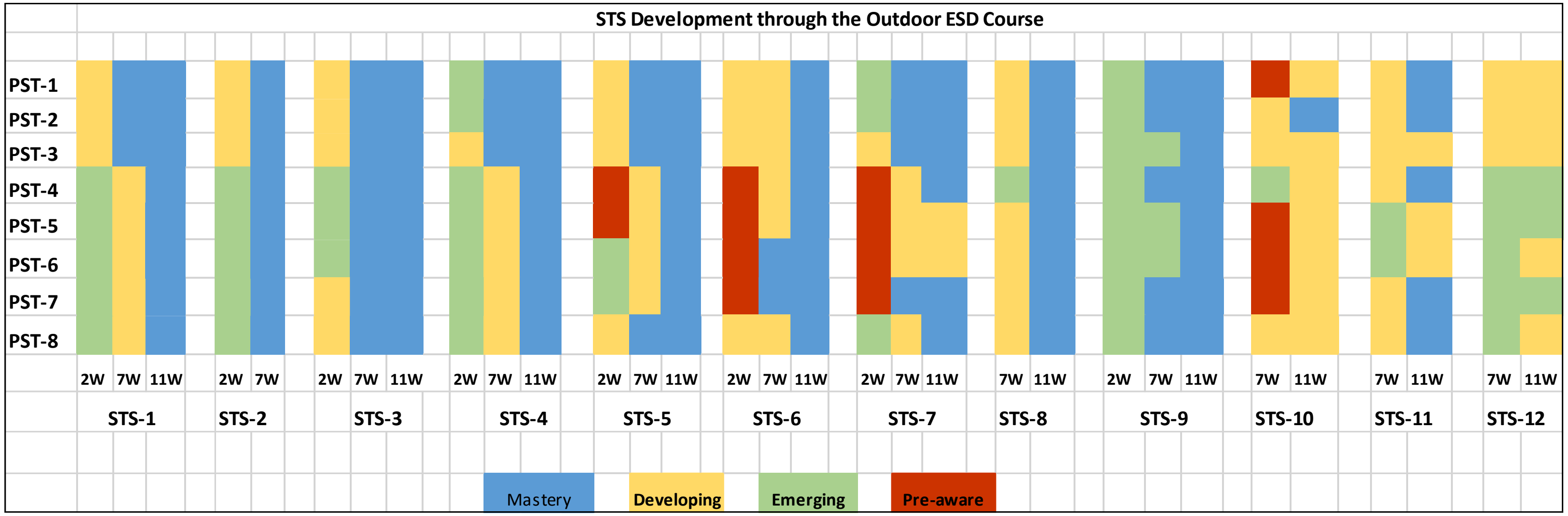

Figure 4.12 Participants' STS Development through the Outdoor ESD Course

CHAPTER 5

DISCUSSION, CONCLUSION AND IMPLICATIONS

This chapter presents discussion of the results, conclusion and implications for science teachers, science teacher educators, curriculum developers and ESD educators.

5.1 Discussion of the Results

Discussion of the results is presented in three stages which are competencies for science teachers to become ESD educators, STS measurement tools and PSTs' current level of STS and finally developing systems thinking skills through an outdoor-based ESD course.

5.1.1 Competencies for Science Teachers to Become ESD Educators

The main purpose of this thesis was to explore how science teachers could become ESD educators. The required competencies for science teachers to become ESD educators were explored through gap analysis as the first step to achieve the main purpose.

Changing perspectives in science and SE due to the paradigm shifts has brought up the discussion related to the role of science teachers in the 21st century. The main reason for these discussions is the current state of the world as current problems we face in the 21st century are complex, and there are wicked sustainability problems such as climate change, poverty, desertification, degradation of the ecosystems, unsustainable consumption and exploitation (UNECE, 2011; Wiek et al., 2011). As stated by Capra and Luisi (2014), global problems of today like climate change, food security and energy cannot be understood in isolation. They are all systemic problems which are all interrelated. Therefore, such problems need systemic solutions that could only be possible by creating sustainable societies that work with the rules of nature.

Today, the need for sustainability has drawn more attention in order to promote people to question their own life styles and current system, encourage them to live in a sustainable way and build sustainable societies (e.g., UNECE, 2011). As education is seen as a key factor to achieve sustainability (UNCED, 1992), individuals' competencies including teachers have been discussed at all levels of education programs from pre-school to higher education (e.g., Rieckmann, 2012; UNECE, 2011). Accordingly, with the major purpose to equip STs to become ESD educators, the first step achieved in this thesis was to investigate competencies for STs and ESD educators. As a result, systems thinking has arisen as a critical competency for STs to become ESD educators.

The importance of systems thinking has been addressed in both SE and ESD literature. In ESD literature, for instance, Sleurs (2008) determined competencies for ESD educators such as values, emotions and systems thinking. The authors determined specific systems thinking skills for teachers. Furthermore, UNECE (2011) addressed that in all education fields educators should have ESD competencies, and it was reported that systems thinking is one of the core competencies for ESD educators.

Within the framework of the above mentioned need, a considerable research focused on developing integrative framework for sustainability competencies. Weik et al. (2011), for example, developed an integrative framework of sustainability competencies and identified systems thinking as the critical competency for sustainability. Similarly, Rieckmann (2012) reported that systems thinking is one of the most important sustainability competencies that students should develop in higher education. In ESD literature, systems thinking has also been accepted as a component of sustainability literacy as well (e.g., Nolet, 2009; Strachan, 2009).

The importance of systems thinking has also been emphasized in SE literature. A number of researchers pointed out that students in the 21st century should be educated as systems thinkers (e.g., Assaraf & Orion, 2005, 2010; Chandi, 2008; Hogan & Weathers, 2003; Keynan et al., 2014; Kali et al., 2003; Shepardson et al., 2014). Furthermore, a number of researchers (e.g., Burmeister et al., 2012; Carney, 2011; Choi et al., 2011, Dutton-Lee, 2015; Foley et al., 2015), implied that sustainability concept should be integrated into SE programs and science teachers' systems thinking skills should be developed.

In the same way, systems thinking has emerged in the last SE framework developed by NRC (2012). In the report of NRC (2012), systems thinking has been addressed especially in science and engineering context. This has been pronounced as a good effort to put forward systems thinking in SE framework. However, although systems thinking has been included, it is criticized that the report holds limitations in terms of sustainability perspective. In a recent paper, for instance, Zeidler (2016) stated that STEM addressed by NRC (2012) lacks socio-cultural perspective in order to raise responsible and informed citizens in the world. Similarly, Feinstein and Kirchgasler (2014) asserted that new SE framework lacks social, ethical and political dimensions and emphasizes a narrow vision of sustainability. It could be interpreted that systems thinking has not been emphasized in a broader sense by NRC (2012).

As a result of the gap analysis carried out in this thesis, SE and ESD researchers emphasized that Turkish science teachers do not have the required competencies for ESD. They also stated that most of the science teachers in Turkey cannot define sustainability and ESD because ESD is not included in the teacher education programs. Similarly, it was addressed by several researchers for Turkish samples that pre-service teachers (including science teachers) don't have an integrated understanding of sustainability (e.g., Alkış & Öztürk, 2007; Sağdıç, 2013; Şahin, 2008). The reason for this could be that lecturers in the teacher education programs do not integrate sustainability into their lectures, and they do not have a holistic view of sustainability (Cavas et al., 2014). As a result, a number of research papers related to teacher education in Turkey (e.g., Alkış & Öztürk, 2007; Kılınç & Aydın, 2011; Şahin, 2008; Tuncer et al., 2006; Tuncer, 2008) stress that ESD should be integrated into teacher education programs. The situation is not different in other countries. For instance, in a recent study conducted in Spain, Cebriyan and Junyet (2015) have reported that pre-service teachers do not have competencies related to ESD. That is, teachers do not have a holistic understanding of ESD in which social, economic, environmental and cultural aspects are interrelated. Similarly, in another study employed in Germany, Burmeister, Eilks and Jacob (2013) noted that science teachers do not have enough knowledge and skills related to ESD and they rarely apply holistic structure of ESD (combining social, economic and environmental aspects) to their lectures. In Finland, Juntunen and Aksela (2014) also emphasized that science teachers should be equipped with ESD skills in order to help their students to cope with the changing world.

Consequently, results of the gap analysis section of the current study are consistent with the relevant literature, and it is suggested that there is a need to develop ESD competencies of science teachers, and especially, systems thinking as a critical skill for both SE and ESD. Hence, the gap to be fulfilled for STs becoming ESD educators is systems thinking skills.

5.1.2 STS Measurement Tools and PSTs' Current Level of STS

5.1.2.1 Systems Thinking Skills and Measurement Tools

After determining systems thinking as the core competency for science teachers to become ESD educators, the second question of the thesis was related to measurement of STS. Before beginning with developing the measurement tools, however, twelve systems thinking skills in SE and ESD context have been determined based on the relevant literature (e.g., Assaraf & Orion, 2005; Hargens, 2005; Nolet, 2009; Sleurs, 2008; UNECE, 2011).

The first skill was defined as identifying aspects of sustainability (STS-1) and was described by several researchers. Nolet (2009), for example, explained that systems thinking is not only related to ecological relationships but also related to identifying the links among ecological, social and economic systems. Doucette et al. (2012) also noted that identifying social, economic and environmental aspects of sustainability was one of the components of systems thinking. Similarly, the skill for identifying aspects of sustainability was emphasized by Sleurs (2008) and UNECE (2011) as one of the competencies for ESD educators. The key concern of systems thinking is related to understanding relationships and interactions in a system (Sterling et al., 2005). This system could be any system such as a natural system, an economic or social system. A systems thinker is able to recognize holistic nature of sustainability, and he/she could evaluate a system from diverse aspects of sustainability. For example, a teacher who holds this skill could help students look at issues from a broader perspective as considering social, environmental and economic aspects of the issues (e.g., Sleurs, 2008). As the results of this thesis indicated that, identifying aspects of sustainability could be the first step to explore STS in ESD context.

Seeing nature as a system (STS-2) has been accepted as one of the STS in this study because, as Capra (2005) stated, living systems constitute integrated systems and an ecosystem could not be understood by dividing it into small parts; hence, nature should be seen as a living system (Capra, 2005). Similarly, Hargens (2005) suggested integral ecology framework in order to understand environmental systems from holistic perspective. Individuals who could identify aspects of sustainability could also recognize natural systems from a holistic notion. Natural systems do not only have economic value, they also have social, environmental, aesthetic and cultural values. Therefore, it is important to see natural systems in an integrated way, not in a reductionist way (e.g., Capra & Luisi, 2014). Having this skill could help both students and teachers understand integrative structure of complex systems in science and sustainability. Only with this systemic view, we could produce solutions to multidimensional problems of this century.

Identifying components of a system (STS-3) was the third skill explored as in the study. It has been defined as identifying components in any system such as a lake system, a forest system or any case related to sustainable or unsustainable use of a system. Identifying components of a system was also described as one of the systems thinking skills by several researchers in different contexts. For example, Assaraf and Orion (2005) defined the skill in the earth system context (identifying components of the earth system). Furthermore, Shepardson et al (2014) adapted this skill to the climate system, and they defined it as identifying components and interactions in a climate system. Doucette et al (2012) defined the skill in sustainability context as identifying conflicts in a sustainability issue. This skill was explored as one of the basic and fundamental characteristics of systems thinking in this thesis. As the results revealed, in order to achieve a higher skill like evaluating interactions in a system, first, individuals need to be able to recognize various components in a system.

The fourth systems thinking skill defined in the context of this thesis was analyzing interconnections among the aspects of sustainability (STS-4). There are a number of definitions related to interconnections among the aspects of sustainability as a component of systems thinking. Nolet (2009), for example, stated that systems thinking requires understanding interconnectedness among social, economic and environmental aspects. Similarly, Capra and Luisi (2014) asserted that current world problems are systemic and interrelated; therefore, they need systemic understanding and systemic solutions. Therefore, in order to understand complex and systemic problems and find systemic solutions STS-4 was considered as an important skill that a systems thinker should have. Therefore, the skill to make interconnections among the aspects of sustainability was assumed as more challenging and complex than previous skills (STS-1, STS-2 and STS-3).

The fifth of the twelve systems thinking skills was defined as recognizing hidden dimensions in a system (STS-5). It was implied that systems thinker should recognize hidden dimensions in a system that could not be seen at first glance. One of the authors who defined the skill as a component of systems thinking is Assaraf and Orion (2005). The authors described it as recognizing dimensions in a hydro-cycle system that could not be seen at first glance. Moreover, STS-5 could be linked to identifying components and analyzing interconnections in a system in ESD context because today's complex problems were interrelated and could not be understood in isolation (e.g., Capra & Luisi, 2014). For example, individuals could make connection among population increase, agriculture, culture, land use change, deforestation, food production and consumption, economy, water, climate change and biological diversity loss, and they could understand the interrelation among these problems. Beyond understanding the interrelations, a system thinker could realize hidden components in these complex problems such as being aware of the life-cycle process of the things used every day. Therefore, recognizing hidden dimensions is one of the vital skills that requires more than making interconnections among the aspects of sustainability (STS-4).

The sixth skill determined in this thesis possesses a different perspective compared to the former ones, which were related to seeing nature as a system of interconnections and hidden dimensions. Recognizing own responsibility in the system (STS-6) is related to personal responsibilities, personal choices in life, and it is important in both SE and ESD. As reported by a considerable number of authors in the SE and ESD literature, there is a need to raise globally responsible citizens who could take action for sustainability (e.g., Carter, 2008; Choi et al., 2011; Moseley et al., 2015). Being aware of how our actions, behaviors or decisions are have an impact on other people's lives, and nature could help us see the bigger picture (Zulauf, 2007). Therefore, a systems thinker should be aware of his/her personal role and take responsibility for the choices made during the day. UNECE (2011) also reported recognizing own responsibility as one of the competencies for ESD educators. Similarly, Sleurs (2008) described that a teacher should be aware that he/she is a part of the system and what role he/she plays in the system. For example, a science teacher could teach students to appreciate the impact of science and technology on our life, but also help them realize the environmental, social, ethical and moral impacts and promotes students to realize their personal responsibilities on these impacts. The previously mentioned characteristics of systems thinking could only provide a partial picture yet, this skill, recognizing own responsibility holds a strong impact on the individuals to transform their life for sustainability. Therefore, it is not enough for a systems thinker seeing nature as a system, making interconnections among the aspects of sustainability and recognizing hidden dimensions, but it is also required to recognize personal responsibilities.

Furthermore, another skill was defined as considering the relationship among past, present and future (STS-7). Assaraf and Orion (2005) described the skill as a component of systems thinking; *thinking temporarily: retrospection and prediction.* The authors noted that students should able to understand that present interactions might be the result of the past events, and that future events could be predicted based on the present actions. Considering the relationship among past, present and future is important that individuals could draw lessons from the past events by making decisions for the present and future. Similarly, UNECE (2011) reported that understanding the relationship between past, present and future as one of the competencies for ESD with an explanation that educators could critically analyze past and present events while exploring alternative futures for sustainability (UNECE, 2011). Holding this skill is important because while discussing sustainability issues, individuals could realize that every problem and every issue has a history and evaluating the history of the problems could open a new perspective for the individuals. As Einstein said, “no problem can be solved from the same level of consciousness that created it”. If people are aware of the consequences of the problems in the past, they could make healthy decisions for today and for the future.

Recognizing cycling nature of the system (STS-8) was the eighth systems thinking skill defined in this thesis as one of the key characteristics of systems thinking, and it was revealed in both SE and ESD. The skill was defined as understanding natural systems work in cycles, and natural cycles are related to each other. Having this skill is important in SE because teachers could realize the interactions among the natural cycles such as carbon cycle, water cycle and human interference on them instead of explaining the cycles in isolated parts. Therefore, it is critical to understand holistic structure of the natural systems. This skill is also important for ESD since individuals could realize that they are all part of this cycling system. Thus, this skill could contribute to both SE and ESD context in terms of developing STS. In the literature, Assaraf and Orion (2005) described the skill as a component of systems thinking and emphasized that it refers to understanding the cycling nature of the world such as hydro-cycle system including sub-cycles. Keynan et al. (2014), on the other hand, included cyclic thinking as a systems thinking skill in ecology context. Capra and Luisi (2014) used the skill for recognizing cycling system in the context of sustainability and suggested that people are dependent on the cyclical process of nature. Thus, the related literature defined and used STS-8 in identical meanings.

The skills for developing empathy with people (STS-9) and with non-human beings (STS-10) were defined as affective aspects of STS and were explored as complex and gradually developing skills in this study. Sleurs (2008) addressed that building empathy with people is related to emotion domain of ESD competencies, yet it is also related to systems thinking because it helps us develop worldviews and systemic view of the world. Moreover, by developing empathy, it is possible to understand people's needs or perspectives behind their actions without blaming them (e.g., Sterling et al., 2005). What is more, empathy with non-human beings was also included as a component of systems thinking. Because, as Sleurs (2008) reported, building empathy is not only related to people, it is also related to non-human beings and the whole nature (Sleurs, 2008). As mentioned before, competency term has been defined in this thesis as including both affective and cognitive components. In order to show a broad picture of systems thinking, affective components were included as characteristics of STS. Because holding positive affective skills like building empathy with people and nature could develop individuals' intention to take action for sustainability (e.g., Sleurs, 2008).

Another skill related to affective aspects of STS was determined as developing sense of place (STS-11). Sense of place was suggested in this study as a systems thinking skill because sense of place is a multi-dimensional concept, and it is related to holistic view of ESD (Moseley e al., 2015). Through developing sense of place, individuals could understand complex nature of the places, and they could feel a sense of connection. Tilbury & Cooke (2005) pointed out that systems thinking help individuals build a sense of connection to the places. In the same way, Sleurs 2008) defined building sense of connection as a component of systems thinking for teachers in ESD. The individuals who have this skill will look at the issues from a wider perspective and will restore their connection with the places, nature, other people and the whole world (Sleurs, 2008). Sense of place revealed in this study was related to building deep and meaningful connections with the places. As Ardoin (2006) described, sense of place refers to attributing different meanings to a place such as psychological, political, biophysical and feeling relatedness. Sense of place was assumed in this thesis as one of the complex and higher order skills of systems thinking. Sense of place combines psychological, environmental, cultural, social, economic and political concepts together and develops a healthy sense of connection with the places (Ardoin, 2006). Moreover, as expected in this thesis, outdoor education contributed to developing sense of place of the individuals. Likewise, Orr (2004) noted that the study of the local places provides a wider, interconnected understanding of the places and ultimately, "landscape shapes mindscape" (p.93).

As consequence, as it is described above, both affective (e.g., building empathy, sense of place) and cognitive aspects (e.g., identifying components, analyzing relationships) were included as systems thinking skills for science teachers to become ESD educators in this thesis. This is one of the features that distinguishes this research from many similar ones as affective aspects have generally been neglected in SE. As Kauertz et al. (2012) reported, for example, competencies in SE are mostly evaluated by cognitive aspects, and affective aspects are ignored. Littledyke (2008) also argued that affective and cognitive domains should be incorporated into SE to develop a sense of relationship and responsibility for the environment. Hence, the systems thinking skills defined and used in this thesis as required competencies for STs become ESD educators are comprised of affective and cognitive domains and are in line with the idea reflected by several authors such as Sleurs (2008), Littledyke (2008), Kauertz et al. (2012) and UNECE (2011).

Likewise, in addition to cognitive and affective aspects, the systems thinking skills of this study also included action aspects. The last skill was defined as adapting systems thinking perspective to personal life (STS-12). It was defined as the most complex and challenging skill in this study. To be specific, it was assumed that the skill for action could be improved after other skills were developed. In line with the UNECE (2011) description of taking responsible actions for sustainability as one of the key competencies for ESD educators, this skill was described as systems thinkers' transformative actions for sustainability. It was asserted that systems thinking helps individuals create a link between knowledge and action and integrate sustainable behaviors into personal life (Sleurs, 2008).

The next step after defining the twelve systems thinking skills according to relevant literature was to develop and/or adapt a series of qualitative data collection tools. STS measurement tools used in this study were essay writing, case study analysis, semi-structured interviews, concept maps and field reports. In the literature, however, the tools used for measuring STS have generally been developed in specific contexts and are in the forms of interviews, written samples, case study, concept maps, and classroom discussions (e.g., Assaraf & Orion, 2010; Brandstadter et al., 2012; Connel, et al., 2012). For instance, Assaraf and Orion (2005; 2010) evaluated systems thinking skills of high school students by using interviews, concept maps, drawings and observations. Yet, they suggested and implemented tools for assessing STS for higher education which are written samples or case studies (e.g., Brandstadter et al., 2012; Connel, et al., 2012; Doucette et al., 2012; Wang & Wang, 2011).

In line with the relevant literature (e.g. Shepardson et al. 2014) and depending on the experience gained during the pilot study, essay writing was used to measure specifically one systems thinking skill (seeing nature as a system-STS-1). Participants were only asked "What does a tree and lake mean to you?" Thus, based on the results, it was revealed that essay writing could be used to evaluate STS-1 in condition that the essay is related to defining a part of a natural system.

Case study analysis was another data collection tool found as useful to measure three STS (identifying aspects of sustainability, components of a system and analyzing interactions among the aspects of sustainability). Case studies are mostly used in sustainability context. Similarly, Doucette et al. (2012) and Connel et al. (2012) measured STS through using cases related to sustainability, and they asked students identify and analyze sustainability challenges in the case.

Concept map was also found as effective tool in SE and ESD context in order to measure PSTs' STS (identifying components in a system, identifying hidden dimensions and recognizing cycling nature). Researcher did not interfere participants' concept map drawings and they drew different kinds of concept maps related to content. According to data analysis results, it was revealed that concept maps could be used to measure, especially, simple systems thinking skills. Tripto, Assaraf and Amit (2013) also emphasized that concept maps could be useful to measure lower level of STS. Moreover, several authors (e.g., Assaraf & Orion, 2005; 2010; Brandstadter et al., 2012; Safayani et al., 2005) addressed that concept maps are powerful and efficient tools to measure systems thinking. Besides, Brandstadter et al. (2012) pointed out that concept maps could be more effective for large scale samples than interviews or observations.

Based on the results of this study, it could be interpreted that essay writing, case study and concept maps used in this study are effective and practical tools for measuring several systems skills, and they could be used for large scale samples easily.

Additionally, interviews were found as useful to measure twelve STS of PSTs in SE and ESD context. Interviews were conducted in order to validate participants' answers in the essay writing, case study, concept maps or field trips. Thus, more detailed, rich explanations were manifested in the interviews. Furthermore, Assaraf and Orion (2005, 2010a, 2010b) conducted interviews in the Earth science context to measure specific systems thinking skills of the students to get in-depth information.

Field reports were also used to measure specific STS of the participants. Yet, field reports may not be effective to give sufficient information; therefore, they need to be validated by other tools.

Another outcome of this study was developing a rubric to evaluate twelve systems thinking skills. Using the rubric including four categories (mastery, developing, emerging and pre-aware) was found effective. The aim was to reveal STS developmental pattern of the PSTs. In systems thinking literature, rubric has been used widely. Rubrics have been described as the most feasible approaches to assess systems thinking skills (e.g., Wang & Wang, 2011; Zulauf, 2007). In a similar way, some researchers used rubric to evaluate STS development process of the students (e.g., Connel et al., 2012; Doucette et al., 2012; Hung, 2008).

When above mentioned tools were compared, interviews could be accepted as the most effective one for providing in-depth information about STS of the PSTs. As described in the relevant literature, interviews enable to explore STS development process of the individuals (e.g., Assaraf & Orion, 2010a, 2010b; Assaraf, Dodick & Tripto, 2013; Goldman, Assaraf & Shaarbani, 2013). Moreover, essays, case study, concept maps and field reports could be used to evaluate STS of the individuals, yet their potential to measure twelve STS is limiting. Therefore, these measurement tools (e.g., concept maps, essay and interviews) could be combined and implemented together for triangulation as suggested by several authors (e.g., Assaraf & Orion, 2010b; Assaraf et al., 2013; Keynan et al., 2014). Thus, triangulation of the tools enables the researcher to measure STS in a valid and reliable way and avoid getting biased results.

All these above mentioned tools were tested to determine PSTs' current level of STS.

5.1.2.2 PSTs' current level of STS

Before the main study started, STS measurement tools were tested, and current STS levels of the PSTs were determined. PSTs' STS was mostly found in the low levels (emerging or pre-aware). Their STS levels were almost identical and except two participants none of the participants' STS was found in mastery level.
For instance, PSTs struggled to identify all aspects of sustainability (social, economic and environmental) and analyze interconnections among them. Moreover, they could not make connection between the issue, their lifestyle and global problems. Nevertheless, two field trips implemented in the pilot study helped them realize nature as a living and cycling system and understand the connection between human life and natural systems.

Exploring teachers' STS level is a new subject in the literature. Systems thinking researchers mostly studied with elementary school and high school students (e.g., Assaraf & Orion, 2005; 2010; Keynan et al., 2014; Raved & Yarden, 2014). However, in a recent study, Dutton-Lee (2015) assessed STS level of the elementary pre-service and in-service science teachers in water cycle context. She found that teachers' STS (e.g., identifying components and processes, interactions in a system) was in the low level (novice or recognition). That is, pre-service and in-service teachers struggled to identify components and relationships in a system, exploring hidden dimensions and realizing human impact on the system (Dutton-Lee, 2015). Similarly, in another study, Hmelo-Silver, Marathe and Liu (2007) explored that pre-service teachers hold limited understanding of complex systems, and therefore, they struggled to teach complex systems to their students. It was also reported that teachers hold limited knowledge and skills to teach complex structure of sustainability (Summers, Child & Corney, 2005). For this reason, there is a need to foster STS of the pre-service and in-service science teachers as Barak and Dori (2009) emphasized. The authors suggested that science teachers need to hold and

practice systems thinking skills as one of the higher order thinking skills; therefore, courses in higher education could be designed to develop teachers' skills.
Results of the present study showed that PSTs' current level of STS was found in the low levels, and the relevant literature supported these results.

5.1.3 Developing STS through Outdoor based ESD Course

The major idea of the thesis was to investigate how systems thinking skills of PSTs could be developed through outdoor based ESD course. In line with this major target and through the research design, PSTs' STS levels were assessed three times during the course. At the beginning of the course, initial level of STS was determined through the first module of the course by using the developed instruments such as essay writing, case study-I and interviews-I and rubric. During the course, for about eleven weeks, after the implementation of second and third modules, PSTs' STS development were realized by the use of the following data collection tools such as case study II, field reports (I-III-III and IV), interviews (II-III) and concept maps (I-II).

The results indicated that although participants' initial STS were found in low levels (emerging, pre-aware), most of the PSTs' STS were developed to higher levels (developing and mastery) after the second and third modules. All of the participants reached to mastery level in eight skills (identifying aspects of sustainability, seeing nature as a system, identifying components of a system, analyzing interconnections among the aspects sustainability, recognizing hidden dimensions, recognizing own responsibility in the system, recognizing cycling nature of the system and developing empathy with people). Some PSTs also developed complex skills (considering relationship between past, present and future, developing empathy with non-human beings and sense of place) to mastery level, yet some of them stayed in the developing and emerging level. On the other hand, none of the participants reached to mastery level in the skill of adapting systems thinking perspective to personal life.

For instance, after outdoor trips, results revealed that all of the participants could identify all aspects of sustainability although most of them defined sustainability in a simple way such as reducing waste and recycling at the beginning of the course. Similarly, Foley et al. (2015) found that pre-service teachers who attend in a sustainability course developed their definitions of sustainability from simple to more complex. Accordingly, in this thesis, the development of PSTs' skills could be explained through conducting field trips to Eymir Lake. During the field trips, PSTs explored Eymir Lake from different perspectives (ecosystem, water quality and human use). In this way, they discussed multiple aspects of sustainability.

Similarly, all of the participants in this study described nature as a living system and recognized after the course that human depends on the nature. The reason for this could be that outdoor trips played an important role in helping them understand natural systems by feeling, touching and observing nature directly. Beames et al (2012) asserted that outdoor education helps individuals understand complex systems such as relationships between plants and animals, flow of energy and human impact on nature. Lugg (2007) also emphasized that through outdoor education individuals could understand nature, its social, ecological, aesthetic value and humans' relationship with nature.

Another part of outdoor activities which were "gardening and composting activities" contributed especially to developing participants' skills of recognizing their own personal role in the system and understanding of the cycling nature of the system. They explained that they could transform linear system created by people to cycling system through changing their personal actions. They also realized that they were part of a global system. This finding is in line with those of Assaraf & Orion (2010b). They also found that outdoor activities could help students understand cycling aspects of the Earth systems and human role in the system. PSTs experienced how the cycles work in nature by making compost and creating a garden; thus, they built a sense of connection with the soil. For these reasons, they might have better understood how natural cycles work and develop their skills. Nelsen (2016) also explored that making compost for years helped the author understand her personal role in the world and developed his sense of connectedness. Similarly, Capra (1999) stressed that growing a school garden, harvesting and composting help individuals understand intersections among the natural cycles and realize how humans are part of the web of life. Capra (1999) also emphasized that gardening is a good project for experiencing systems thinking.

Another important outcome of this study was that there was a complex and hierarchical relationship among the twelve systems thinking skills. As displayed in the results section (Figure 4.12), there could be four hierarchical levels among the skills. For example, the skill of adapting systems thinking perspective to personal life (STS-12) was found as the most complex skill and places at the top level. Moreover, most of the participants' level of STS-12 was evaluated as emerging and developing. Assaraf and Orion (2005) also demonstrated that there was a hierarchical relationship among the components of systems thinking. For instance, thinking temporarily which is related to considering the relationship between past, present and future was found as a higher order skill by Assaraf and Orion (2005, 2010). In this study, this skill was also explored as one of the complex skills. That is to say, PSTs showed a gradual development, and their skill was found in the developing and mastery level at the end of the course. The development of this skill (considering the relationship among past, present and future) could be related to content and implication of the outdoor activities. Specifically, in Eymir field trips, PSTs discussed the change in the lake over time, and they learnt about the past developments in the lake and how to protect Eymir for the future. Nevertheless, there could be more outdoor activities and discussions related to time dimensions to develop all participants' STS.

In the same manner, most of the participants demonstrated slow development in other complex skills (building empathy with non-human beings, sense of place and adapting systems thinking perspective to personal life) through the course, yet all of them reached to developing and mastery levels. In the literature, it is emphasized that outdoor learning environments contribute to developing affective domains such as relationship with nature and developing empathy with the environment (e.g., Higgins & Kirk, 2006; Martin, 2004, 2008; Lugg, 2007). The development of these skills like building empathy and sense of place could be attributed to field trips in the course. Visiting Lake Eymir four times through the course and constructing a garden in the faculty could help PSTs develop their STS. For instance, in the literature, it is addressed that place-based outdoor education improves individuals' sense of place (e.g., Semken & Freeman, 2008; Semken et al., 2009; Wattchow & Brown, 2011). In this study, PSTs developed a sense of place during the field trips. That is, they attributed multiple meanings to Eymir (e.g., psychological, biophysical), and they developed a sense of connection and responsibility. The reason for this might be that PSTs examined Eymir from different perspectives, and they learnt how Eymir had changed over time. Moseley et al. (2015) also argued that in order to foster sense of place, pre-service teachers should be promoted to question how their local environment has changed over time and how they could contribute to sustainability of the local natural resources.

PSTs' last skill of adapting systems thinking perspective stayed in the emerging and developing level. Some participants talked about their intention to take transformative actions for sustainability, yet some of them described to take simple actions for sustainability like recycling, reducing consumption. It was explored that this skill was one of the most complex STS to develop in a course since none of the participants' skill was found as mastery. The reason for that could be holding systems thinking perspective might sometimes cause individuals to think that their actions don't have any influence on coping with the global problems. Agyeman and Angus (2003) also argued that although recognizing the bigger system is important, it could sometimes cause individuals to realize that their actions may not be effective to make significant changes. During the interviews, some participants expressed that saving Lake Eymir will not have an influence on sustainability, so we need to consider the whole system. Therefore, some participants' skill of adapting systems thinking perspective to personal life stayed in the emerging level.

Looking at the STS developmental patterns of the PSTs important results were obtained in the current thesis. The results unearthed that PSTs' STS developmental patterns change from person to person. For example, as shown in Figure 4.11, some participants' initial STS was found as higher than other participants, and they demonstrated a gradual development during the course. However, participants whose initial level of STS was found low indicated a substantial development in their skills. Assaraf and Orion (2010a) also found a similar result in their STS research. The authors explored that STS developmental patterns change from student to student, and some students' starting point was higher than other students, and they showed a gradual increase in their skills. However, students whose level of STS was lower than other students demonstrated a drastic increase in their skills. It could be inferred that PSTs' STS development could differ from individual to individual based on their background. The reason of these individual differences could be depending on individuals' own beliefs, values and behaviors, and these differences influence their way of thinking (Sterling et al., 2005). For instance, how they could explain a natural system such as a tree could be influenced by their beliefs, values and interests (Sterling et al., 2005). A person who is interested in healthy food will probably deal with food quality, how food is produced and treated (Sterling et al., 2005). In the current study, some participants already had some ideas about sustainability issues, and they gradually developed their skills through the course. For example, as described in the sample characteristics in the methodology section one male participant grew up in a small village, he was more knowledgeable and motivated about gardening practices than other participants;

therefore, he was actively involved in this part of the course and developed his skills. It could be inferred that considering participants' background, their beliefs and perspectives are important to interpret their STS developmental patterns.

Individual differences could be also considered in the classrooms. For instance, a teacher might consider individual and shared interests in her/his classroom and encourage students to respect individual differences and different viewpoints (Sleurs, 2008). Therefore, individual differences could be taken into consideration in systems thinking research in SE and ESD context.

As a result, it was found out that outdoor ESD course could be beneficial in developing STS of the PSTs as described by several authors (e.g., Assaraf & Orion, 2005; 2010; Keynan et al., 2014). The relevant literature unearthed that creating a multidisciplinary learning environment by combining both indoor and outdoor classes provided individuals to develop some aspects of systems thinking skills such as identifying aspects of sustainability and relationships among them (e.g., Carney, 2011; Hill, 2012; Garner et al., 2014). As the results of the current thesis indicated, other aspects of STS like seeing nature as a system, recognizing cycling nature of the system, building sense of place or building empathy with people, and nature could be improved through outdoor education. Outdoor education provides a rich learning environment to understand complex systems and relationships among them and foster individuals' connection with the places (Beames et al., 2012; Hill & Brown, 2014). As Assaraf and Orion (2005) addressed, outdoor education should be integrated into all school programs as much as possible.

The last research question investigated in this study was to what extent PSTs reflect their systems thinking skills to instructional planning under the light of the outdoor ESD course. The results illustrated that PSTs could reflect a number of STS in their lesson plans. To be specific, PSTs were able to integrate the skills they reached into the highest level during the course. Burmeister et al (2012) also found that preparing lesson plans contributed to developing higher order thinking skills of the science teachers and looking at the sustainability issues from a broader perspective. In this thesis, PSTs especially emphasized aspects of sustainability, components and relationships in a system in their lesson plans as they improved these skills through the course. As Strachan (2012) reported, teachers could design and facilitate learning environments in order to develop students' systems thinking. Therefore, this result is important in terms of professional development of PSTs because PSTs who have systems thinking skills could assist their future students with developing their skills in their real classrooms.

5.2 Conclusion and Implications

This study has the following conclusions:

Systems thinking skills have been explored as a core competency for science teachers to become ESD educator based on the gap analysis.

Twelve systems thinking skills have been determined to seal the gap in SE and ESD context according to the relevant literature.

A series of qualitative data collection tools were developed and adapted in order to measure systems thinking skills. The triangulation of the data coming from different measurement tools provided reliability and validity of the tools and it was concluded that these tools (essay writing, case study analysis, interviews, concept maps and field reports) could be used to measure specific systems thinking skills of PSTs in SE and ESD context.

PSTs' systems thinking skills were developed through an outdoor-based ESD course. Before the main study started PSTs' current level of STS was mostly found in low levels (emerging and pre-aware), and it was concluded that there was a need to develop STS level of PSTs.

An outdoor ESD course was designed and pilot tested. The 12 STS defined have been assessed through the course. The results highlighted that outdoor ESD course holds a potential to develop systems thinking skills of the PSTs. PSTs developed most of their systems thinking skills through the course. As previously stated, outdoor education provides a multidisciplinary learning environment to explore interrelatedness, complexity in the natural systems and develop sense of place, build empathy with humans and non-human beings. In this way, incorporating outdoor education to ESD could contribute to improving systems thinking skills of PSTs.

It is shown through the results that there were four level of hierarchical relationships among the twelve skills (Table 4.12), and PSTs showed a gradual increase in the levels of complex skills (e.g. STS-10, STS-11 and STS-12).

It is unearthed that PSTs' STS developmental patterns change from person to person during the course. According to participants' initial level of STS and their background, they demonstrated different STS developmental patterns through the course.

Lesson plan analysis have provided that PSTs could reflect several STS in their instructional planning; therefore, lesson plans might be considered as a tool to investigate STS of the pre-service science teachers.

Furthermore, the thesis has several implications for science teachers, science teacher educators and curriculum developers. In this century, systems thinking has been recognized as an important skill to be able to understand systemic problems of the world and provide systemic solutions. For a sustainable future, the interest and the will are increasing to educate science teachers as ESD educators. Hopefully, there are attempts both in Turkey and in the world to integrate sustainability concept into SE programs (e.g., MoNE, 2013; NRC, 2012), and these efforts are very important for the future. MoNE (2013) integrated sustainable development concept into the new SE curriculum in order to help students realize the relationship between environment, economy and society and increase sustainability awareness of the students.

In addition, in USA, the new SE framework developed by NRC (2012) emphasized a new vision for SE in terms of integration of science, technology, engineering, and Mathematics (STEM) so that students could understand how science and engineering are important to cope with the major problems of the society today. Turkey is also following these developments related to STEM education.

In the last years, a new book namely “Educating Science Teachers for Sustainability” has been published by Stratton, Hagevik et al. (2015) to create a discussion about educating science teachers for sustainability in different settings-both formal and out of school. This book included many empirical examples related to integrating sustainability into science teacher education programs in order to teach children about sustainable practices and sustainable living. These developments demonstrate that there is a tendency in SE field towards interdisciplinary teaching including sustainability and STEM education and developing an integrated way of understanding. These attempts both in Turkey and in the world are important to develop students’ skills to overcome complex, wicked sustainability problems of the world.

Therefore, the results of this thesis are promising to open a new window to educate pre-service and in-service science teachers as ESD educators by developing their systems thinking skills. Twelve systems thinking skills presented here could be integrated into science education courses; thus, pre-service teachers could develop their skills such as identifying multiple aspects of sustainability and relationships among these aspects, hidden dimensions in a system or building empathy with people. In this way, pre-service science teachers equipped with systems thinking skills could prepare their future students to think and act for sustainability.

The design and results of the thesis provide an initial picture for integrating SE, ESD, outdoor education and systems thinking promising to make an important contribution to sustaining investigations related to collaboration between SE and ESD research fields in order to educate science teachers for a sustainable future.

5.3 Recommendations for the Future Researchers

The present study has several unique contributions. First of all, twelve systems thinking skills have been defined in SE and ESD context for pre-service science teachers to become an ESD educator. These skills could be integrated into other disciplines in teacher education in order to develop ESD competencies. Furthermore, some simple skills such as identifying aspects of sustainability, components of a system, recognizing hidden dimensions or building empathy with people could be incorporated into elementary school level. Science teachers who have systems thinking skills could develop their students' skills in their courses. These skills could be adapted to other disciplines in teacher education to develop teachers' ESD competencies. In addition, each systems thinking skill could be studied in detail in specific contents of SE and ESD. Secondly, multiple data collection tools (e.g., Essay writing, case study, interviews) as well as the rubrics were developed and adapted to assess systems thinking skills of PSTs. It is recommended that these tools could be used in SE and ESD context, or they could be adapted to different contexts in teacher education to support validity of the tools. Essay writing, case study and concept maps could be used for larger samples to measure a number of STS. Nevertheless, in order to measure twelve STS, researchers could only use interviews, and they could adapt interview questions according to their context. Moreover, lesson plans could be used to evaluate systems thinking skills of pre-service and in-service teachers in the future. Thirdly, participants' individual differences should be considered in systems thinking research. Therefore, future researchers could study each participant as a case in order to get detailed information about the impact of participants' background on their systems thinking skills development. Moreover, it is recommended that a follow up study should be conducted in order to investigate how participants reflect systems thinking perspective to their professional and personal life. Furthermore, outdoor ESD course was a new course designed for developing systems thinking skill of PSTs. Outdoor activities in the course were developed under two themes: *What is sustainable use of a system?* and *Sustainability Solutions*. New sustainability topics could be integrated into these themes and researchers could develop a new content for outdoor ESD course depending on their context.

To conclude, research in systems thinking in SE and ESD context is in a preliminary stage especially in Turkey; therefore, it is suggested to employ more research to test findings of this study in different SE and ESD courses, different levels (e.g. elementary level), different teacher education disciplines and different cultures. In order to overcome today's systemic problems, all individuals should learn to see the world from systems thinking perspective and realize that everything is interrelated in the world. As Capra (2005, p. 29) described, creating sustainable systems is possible through education:

> Nature demonstrates that sustainable systems are possible. The best of modern science is teaching us to recognize the processes by which these systems maintain themselves. It is up to us to apply these principles and to create systems of education through coming generations so that they can learn the principles and learn to design societies that honor and complement them.

FINAL THOUGHTS

This was a long and challenging, but at the same time, a joyful journey. In this journey, as a researcher I wanted to do something worthwhile with educating science teachers and indirectly educating future generations. I feel that I did a meaningful contribution to SE and ESD field by determining 12 systems thinking skills in SE and ESD context, developing and adapting several STS measurement tools and designing an outdoor ESD course.

Indeed, my view of outdoor education and ESD have been shaped not only by reading the relevant literature but also through my seven years experiences as an educator and researcher in this field. I developed my field experiences while attending in many workshops, summer schools and courses and I tried to integrate my experiences into the outdoor ESD course. Through these experiences I developed my sustainability understanding, my own perspective related to outdoor education and ESD. I was really impressed by several authors' critics and thoughts related to sustainability, education and systems thinking such as David Orr, Fritjof Capra and Stephen Sterling. Finally, I realized that holistic perspective is very important in order to understand our personal role in this planet and to promote transition towards a sustainable future. Therefore, I chose to focus on systems thinking research in my PhD thesis as I believed that we need to change our state of mind not state of the earth.

My passion and self-determined motivation for sustainability helped me deeply focus on each step of this thesis. While designing the research, collecting data and writing thesis, I also witnessed my transition from linear thinking towards systems thinking. In every part of the preparation of this thesis, I realized how systems thinking is valuable and important.

This is an end for now, but in the future I will continue studying on educating science teachers, students and also teachers from other disciplines for a sustainable future while developing their systems thinking skills. Systems thinking and ESD research are not only subject of SE, but they are also related to other disciplines in education since the ultimate goal is to educate sustainability literate citizens for the future. Therefore, I believe that current thesis will inspire all education researchers to integrate ESD and systems thinking studies into their disciplines.

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APPENDICES

Appendix A: ESSAY WRITING

How do you see a tree? What does a tree means to you?

How do you see a lake? What does a lake means to you?

Appendix B: CASE STUDY ANALYSIS

CASE-1 (PILOT STUDY):

ÇORUM TARIM ARAZİLERİ: DOLDURULAMAZ BOŞLUK

(ÇORUM AGRICULTURAL LANDS-UNFILLED EMPTINESS)

Çorum merkezde bazı köylerden geçerken sanki göktaşı düşmüş gibi derin çukurlar görülür. Bu çukurların tabanında su varsa, orada yepyeni bir ekosistem de oluşmuştur. Sazlıklar arasından kuşların, kurbağaların sesi gelir. Ne var ki bu manzarayı doğa yaratmaz. O dev çukur aslında verimli bir tarladır; toprağı tuğla fabrikasına gider, ve geriye yeri bir daha dolmayacak bir boşluk kalır.

Biz de işte bu hayatını kaybeden arazilerini görmeye gittik. Rehberliğimizi yapan Çorum Tarım İl Müdürlüğü'nden Mühendis Yaşar Eken, bir tarım alanında herhangi bir endüstriyel üretim yapılacağı zaman izin alınan meciinin başındaki kişi. İzin talepleri ilk olarak Tarım İl Müdürlüğü'ne gelse de, onay süreci başka mercilerin denetiminde ilerliyor. 3 temmuz 2005 tarihinde kabul edilen 5403 sayılı "Toprak Koruma ve Arazi Kullanımı Yasası" uyarınca tarım arazilerinin amaç dışı kullanımı yasak. Bu yasak nedeniyle başvuruları reddedilen işletmelere, 2007 ylında çıkarılan bir yönetmelikle yeni bir yol açıldı. Pek çok işletme önce Maden İşleri Müdürlüğü'nden "kamu yararı" kararı çıkarıyor. Bundan sonra işletme izni almak çok kolay. Bu yasaların içeriğini anlamak kolay, ancak verilen izinlerin sonuçlarının farkedilmemesini anlamak çok zor. Neredeyse 70 yıldır Çorum'da en değerli tarım arazileri, kolayca tuğla üretilebildiği için fabrikalara veriliyor. Resmen Çorum'dan bakarken, tüm dünyadaki manzarayı görmek de mümkün. Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO)'nun verilerine göre son 15 yılda kişi başına düşen tarım arazisi gelişmiş ülkelerde yüzde 14.3, gelişmemiş ülkelerde de yüzde 40 oranında azaldı. Nüfus arttıkça kişi başına düşen toprak oranının daha da düşeceği öngörülüyor. Bir de küresel iklim değişikliği sonucunda kaybedilecek tarım arazileri hesaba katılınca tüm politikaların tekrar gözden geçirilmesi gerekiyor. Çorum'da tarım arazilerini fabrikalara satan köylüler bu durumu çoktan kabul etmiş. Köylü, o toprağı satarak elde edeceği geliri, belki 20 sene çalışarak kazanamayacağını düşünüyor. Fabrika için de durum çok karlı, en sağlam malzemeyi çok az uğraşla kaynağından alıyor. Tarladan kum çıkarana kadar, bazen iki bazen beş metrelik devasa çukular kazan fabrikalar, bu büyük boşlukları ardında bırakıp yeni araziler arıyor. Toprağı alınan tarlalar ne oluyor sorusunu Yaşar Eken, "Taban suyu yüksek yerlerde o alanlar kum çıkarmak amaçlı kullanılamıyor, bataklık oluyor. Taban suyu derin yerlerde arazi yine tarım alanı olarak kullanılıyor, tabi yoğun gübreleme gerekiyor" diye yanıtlıyor. Bir de kaybedilen toprakları değil, toprağını kaybedenleri anlatmak gerek. Toprağını satıp, kökünden kopanları. Onlarda da tıpkı kum çıkarılan tarlalar gibi büyük boşluklar kalıyor. Toprağını satan birçok köyün nüfusu azalmış. Kınık köyünden 55 yaşındaki Hasan Samsak, hane sayısının 60'a kadar indiğini söylüyor. Çünkü tarlasını satan gitmiş. Kendisinin de arazisi olduğunu tuğla fabrikasına vereceğini söylüyor. Çünkü şu andaki ihtiyaçları, gelecek kuşakların gıda güvenliğinden daha öncelikli onun için. Tarhan köyünden 72 yaşındaki Raif Dumanlı, toprağını fabrikaya verip pişman olanlardan; çünkü bir kısmında artık hiç tarım yapamıyor, ektiklerinde de verim yarı yarıya düşmüş. Yine de ısrarla çalışmaya devam ediyor. " Buğday ve pancar ekiyorum. Biz çalışmazsak şehirdekiler de ekmek yiyemez. Mecbur ekeceğiz" diyen raif Amca, o önemli soruyı tekrar hatırlatıyor: Tarımsal üretim durursa besin ihtiyaçları nasıl karşılanacak? Bu soruyu yönelttiğimiz Yaşar Eken, şu anda eskisi kadar fazla mutlak tarım arazisi tahribatına izin vermediklerini söylüyor. Çorum'da 2010 yılında yapılan başvurular sonucunda, 529 dönüm arazinin tarım dışı kullanımına izin verilmiş. 2011 nisan ayına kadar izin verilen miktar henüz 179 dönümdü. Tabi bu izinlerin hemen hepsi için önce " kamu yararınadır" kararı çıkarılmış. Sanki o toprakların tarım için kullanılması kamu yararına değilmiş gibi... Günümüzde toprak kıt bir kaynak haline geldi. Bu sorunda sadece nüfus artışı değil, küresel iklim değişikliğinin olumsuz etkileri de göz önünde tutulmalı. İşlenen tarım alanlarının daralması, yok edilmesi, kirlenmesi ve bozulmasına neden olan olumsuz sürecin hem Türkiye'de hem de dünyada mutlaka durdurulması gerekiyor. Çünkü toprağın yedeği yoktur, tıpkı hayat gibi. Toprağı kaybeden hayatını da kaybeder.

(REC (2012). Retrived from www.vakityok.org)

Q: What does this story tells? Write your thoughts, opinons, feelings

CASE-1 (MAIN STUDY)

VİDEO: “We are losing our pastures in Turkey”

(CNN TURK, 2014. Retrieved from http://tv.cnnturk.com/video/2014/02/24/programlar/para-dedektifi/meralarimiz-yok-oluyor/2014-02-21T1925/index.html)

What does this story tells in the video ? Please, write your thought, opinions, feelings about the story.

CASE-II (MAIN STUDY)

VİDEO: “The most expensive meat is consumed in Turkey**”**

(CNN TURK, 2014 retrieved from http://tv.cnnturk.com/video/2014/04/28/programlar/para-dedektifi/en-pahali-et-turkiye-de/2014-04-25T2215/index.html)

What does this story tells in the video ? Please, write your thought, opinions, feelings about the story.

Summary of the videos: Two real stories explain deterioration of the ecosystems and agricultural lands because of the airport construction and revealing its social, economic and environmental consequences. For instance, in the first video, fertile agricultural lands and pastures are disappeared because of the airport construction and villagers lose their job and they had to move to cities. The second video also display similar problem. Since pastures are disappeared, villagers had to sell their animals and they had to leave their farms and move to the cities. Moreover, the meat price is increasing in the cities as the number of animals decrease.

Appendix C: INTERVIEWS

1. **FIRST INTERVIEWS**

Interview Questions	Measured Systems Thinking Skills
1. What did you say about trees and lake in your essay? Could you explain them again?	STS-2
2. What is your thoughts, opinions about this case (video) ?	STS-4 / STS-9
3. What are the components of this case? What are the relationships between these components?	STS-3 /STS-4
4. Is there any hidden dimensions in this case (video)? What are the relationships between these dimensions?	STS-5
5. Is there any relationship between this case in the video and your life? Please explain.	STS-6
6. Could you give any other examples related to this case? Does this case remind you any other place you heard before ?	STS-7
7. What does sustainability mean to you?	STS-1
8. Now I will ask you questions about Lake Eymir. What does Eymir mean to you?	STS-2
9. How do you evaluate human-nature relationship in Eymir?	STS-2
10. How do you evaluate today and future of Eymir in terms of global problems (Climate change, biodiversity loss, deforestration)?	STS-7
11. In your opinion, How Eymir will look like in the future?	STS-7
12. How do you evaluate Eymir in terms of sustainable use?	STS-1/ STS-4
13.What could be the relationship between your life habits and sustainable use of a lake?	STS-6

2. SECOND INTERVIEWS

Interview Questions	Measured Systems Thinking Skills
1. What does a tree and lake mean to you now ? Did your views change during the course?	STS-2
2. Could you explain the relationships in your concept map? (How did you explain sustainability here?)	STS-3 and STS- 4
3. What does sustainability mean to you now?	STS-1
4. Is there any hidden dimensions in this concept map? (Hidden dimensions are) related to system but they are not seen at first glance)	STS-5
5. How do you define your personel role, your responsbilities relevant to the subjects in your concept map?	STS-6
6. Did you explain natural cycles in your concept map? How the cycles are related to eachother?	STS-8
7. Considering today and past uses of Eymir, how do you visualize Eymir for the future? How Eymir will look like in the future?	STS-7
8. What is your inferences and your conclusion with regards to the interviews with people working or visiting Lake Eymir? How do you evaluate their opinions in terms of sustainability perspective?	STS-9
9. How did you feel in Eymir during the three weeks? (Did you feel connection to other species?)	STS-10
10. Could you explain an important learning moment during these weeks?	STS-11
11. What did Lake Eymir mean to you before the field trips ? Is there any change in your thoughts after the trips?	STS-2/STS-11
12. Throught the course, what changed in your life?	ST-12

3. **THIRD INTERVIEWS**

PART-1 (INTERVIEW QUESTIONS RELATED TO CONCEPT MAPS)

Please draw a concept map by showing the components and relationships with respect to the composting and gardening activities.

Interview Questions	Measured Systems Thinking Skills
1.Could you explain the relationships in this concept map**?** • How do these relationships affect eachother? • Hidden dimensions? • The relationship with the natural cycles • The relationship with the sustainability	**STS-1, STS-3, STS-4, STS-5, STS-8**
2. How do you define your personel role, your responsbilities relevant to the subjects in your concept map?	**STS-6**
3.How do you make relationship between gardening and sustainability?	**STS-4**
4.What was the important learning moment in this gardening class?	**STS-11**

PART-2 (INTERVIEW QUESTIONS RELATED TO LESSON PLANS)

1. What was your main goal in this lesson plan?
2. In which stages did you expect that students could make relationship between sustainability and the subject that you intended to teach?
3. What activities did you include in your lesson plan in order to develop students' systesm thinking skills?
4. In which stages did you expect that you could develop students' systems thinking skills?
5. Did you learn, explore a new thing while preparing this lesson plan?
6. Was this lesson plan different from other plans you prepared before? Please explain.

PART-3 (GENERAL INTERVIEW QUESTIONS FOR EVALUATING STS)

Interview Questions	Measured Systems Thinking Skills
1.What does sustainability mean to you after this course? (please, give me an example related to the course)	**STS-1**
2.Could you see the issues/the problems from social, environmental and economic perspectives after this course? (please, give me an example related to case (video)	**STS-3/STS-4**
3.Could you evaluate the components of a system and the relationships among them from sustainability perspective? (please, give me an example from the case)	**STS-3/STS-4**
4.Could you analyze the relationships among the aspects of sustainability by considering the reason and consequences in a case? (please, give me an example)	**STS-4**
5.Could you determine any hidden dimensions in a system that were not seen at first view? (please, give me an example)	**STS-5**
6.Could you define yourself as a part of the system? and produce sustainable solutions in your life? Please, explain.	**STS-6 /STS-12**
7.Could you think of consequences or the effects of the issues by taking lesson from the past ? Please explain.	**STS-7**
8.Could you explain the relationships among natural cycles? Please, explain.	**STS-8**
9.Could you build empathy with other people in a case or event? I mean, Could you understand other people needs and perspectives? Please explain.	**STS-9**
10.Do you feel that you are connected to nature, the place you live and the people around your community? How did you realize this connection in this course?	**STS-10 / STS-11**
11.Could you integrate systems thinking perspective into your life? How? What changed in your life?	**STS-12**

Appendix D: EXAMPLE FIELD REPORTS

FIELD REPORT-I:

OUTDOOR EXERCISE – I –
SUSTAINABLE USE OF AN ECOSYSTEM: LAKE EYMIR

1. **LEARNING OBJECTIVES**

- Analyze Lake Eymir in terms of sustainable use of natural resources (human use, history, economical value, pollution, social value, future considerations)
  - ❖ Explore the interactions in the ecosystem of Lake Eymir
- Analyze future of the lake in terms of global threats (e.g. biodiversity loss, deforestation and climate change)
- Analyze interactions between human use and the ecosystem of the lake
- Develop sense of connectedness to the nature in Eymir

2. **BACKGROUND**

Once upon a time in Eymir

In 1930s Eymir was a lake among the bare mountains as was described by Mr. Nahid Sırrı Örık as follows:
"The mountains surrounding Eymir was bare and were almost yellow in color. There was neither a house nor a tree around. There were only some reeds and animals bathing in the lake (Anatolian Road notes, 1939)".
Eymir was not green in the 1930s. But during 1950s, after the lake was began to be managed by METU the area was planted. The life in the lake has changed; the area around the lake has become a forest, it was possible to swim and fish in the lake, there were paddle competitions, festivals and tree planting organizations. After a while water quality of the lake has begun to decrease. It has become impossible to swim and the aquatic life has almost diminished because of eutrophication. Nowadays it is possible to see only a few bird and fish species in the lake; like the birds of the Lake the so called Peace Fountain, constructed ones upon a time near the lake, stands alone (Memories from Eymir Lake, 2006)

Q.Considering the history of Eymir what would you infer about today and future uses of Eymir?

3. **RESEARCH- EXPLORING NATURAL SYSTEM OF EYMIR**

Wherever you go in nature, you will see interactions between rocks, atmosphere, oceans, lakes, rivers, and living being that constitute Gaia (Harding, 2009). Through three weeks, you will explore ecosystem of Eymir by considering the interactions among the components of ecosystem. You will examine woodland ecosystem in Eymir, water quality of Eymir and human use in Eymir

A. **WOODLAND ECOSYSTEM IN EYMIR**

In this course, you will observe woodland ecosystem in Eymir. You will explore interactions among the components of this system. You can think about below components while observing the natural systems.

A.1 Solo Exercise- 10 min.

Before you start your observation, let yourself travel back in time to childhood. Remember how it felt in your body when you were a child, as young as five, or as old as ten, to be small, energetic and to be outside with plenty of time. Allow yourself to walk like you did as the child you were to see as you did, to feel as you did. Look around, play in the sand, collect “treasures” hide in small places and peer out, build a nest, draw with a piece of found charcoal skip, talk to a tree, climb a tree, look down a hole. EXPLORE, BUILD, PLAY. GO WILD OR BE STILL. ALLOW THE WORLD TO BE NEW AGAIN.Let yourself be surprised by what happens. Bring a couple of treasures with you (physical things, perhaps a story, sound, song, gesture or movement) and share your wonder with a friend.

- **Then, write your experiences about this exercise. How did you feel? What did you think? What did you remember from the past? Is there something interesting you experienced? Please explain**

A.2 Make your observations by considering the below components.

- Sunlight (dark, shady, light, medium light or others), Wind, Soil (you may identify what covering on the soil), Plants (trees (broad leaved or needled), shrubs and grasses), Animals (birds, insects, reptiles, mammals etc. if you can see), Fungus (where are they located?), Lichens (where are they located?), any dead or burned trees?

- **Write you observation on the below table.**

Table 1.

Observation data sheet

Ecosystem Elements	**Site 1. (define location)**	**Site 2. (define location)**
Sunlight (dark, shady, light, medium light or others)		
Wind		
Soil (you may identify what covering on the soil)		
Plants (trees (broad leaved or needled), shrubs and grasses)		
Animals (birds, insects, reptiles, mammals etc. if you can see)		
Fungus (where are they located?)		
Lichens (where are they located?		
Dead or burned trees		
Others (your observation)		

A.3 Carbon Storage
Follow the steps for carbon calculation in trees:
(You can select different species and different aged trees for your calculation)
Identify the species: ____________________

circumference at breast height (in cm): __________________

Diameter at breast height (in cm): ___________________
(Remember: Diameter= circumference * pi)

The biomass of your tree or shrub (in kg): ____________________
The formula for this is $M=aD^b$
M= biomass
a= species coefficient a (See Table 2)
D= diameter at breast height
b= species coefficient b (See Table 2)

Is this species hardwood or softwood? (The resources you used to help identify your tree species should tell you if it hardwood or softwood.) ______________________

Calculate the amount of carbon in your tree or shrub (in kg): __________________

To do this:
Multiply biomass (M) by 0.521 for hardwood trees.
Multiply biomass (M) by 0.498 for softwood trees.

You may wish to convert kg to tons to make comparisons between your measurement and the carbon counter's measurement of greenhouse gases in the air:

____
(1 metric ton = 1000 kg)

Results:

Table 2.
Species-Dependent Coefficient and Exponent Values for Biomass Equation

Tree Species	a	b
Ash, white	.1063	2.4798
Basswood	.0617	2.5328
Birch, black/sweet	.0629	2.6606
Cedar, Red	.1019	2.3000
Maple, Sugar	.2064	2.5300
Oak, black	.0904	2.5143
Oak, chestnut	.0554	2.7276
Pine, white	.1617	2.1420
Sumac, Staghorn	.0825	2.4680

(http://www.yale.edu/fes519b/saltonstall/biomass2.html - estimate)

4. DISCUSSION OF THE TOPIC
(please answer the following questions)

1. **Think about what you have seen in Eymir this week? What do you infer from your observations?**

2. **Please, draw the diagram or picture of the ecosystem you observed in this course. Think about the interconnections between the elements of woodland ecosystem in Eymir.**

3. **You calculated how much carbon a tree stores in a day. Explain how to use this data for describing sustainability in Eymir.**

4. **Is it possible to set sustainablity in Eymir? What are the possible threats for unsustainability?**

5. **As an evaluation of this outdoor exercise, please answer the following questions:**

   a. **What did you learn in this outdoor experience?**
   b. **What was the most interesting part for you?**
   c. **Whether your thinking about Eymir Ecosystem has changed or not?**
   d. **Do you think about anything to be added, excluded, or changed related to the content, etc.**

References:

Memories from Eymir (2006). Retrieved from https://tr.wikipedia.org/wiki/Eymir_G%C3%B6l%C3%BC
Örik, N. S. (1939). Anadolu Yol Notları (Anatolian Road Notes). Retrieved from https://tr.wikipedia.org/wiki/Eymir_G%C3%B6l%C3%BC

FIELD REPORT IV.

OUTDOOR EXERCISE – IV

TRANSFORMING WASTE TO WEALTH!

1. **LEARNING OBJECTIVES:**

- Help students be aware of the composting process as a part of sustainable system.
- Explore how compost can be transformed to the food
- Help students make connections between natural cycles and composting process.
- Be aware of the individual responsibilities

2. **BACKGROUND**

From a systems' point of view, it is clear that human take from the earth (water, air, food, raw materials, and minerals) and return wastes and pollutants back to the earth. But the earth is limited as regards with its sources (what it can sustainably provide) and its sinks (what it can absorb without harming its future ability to absorb, regenerate, and regulate natural cycles). The key problem is that our economy is fundamentally linear and produces waste whereas earth system work on cyclical basis where waste is recycled (Sterling, Maiteny, Irving, & Salter, 2005). In nature, there is no waste. Waste would not exist because it would not be produced or if it is produced, it would be a resource to be used again. This is the main point of zero waste. For example, when an elephant eats plants, it produces waste and this waste becomes a resource for dung beetle. The goal of zero waste is to eliminate waste concept and turn the waste into resource. In the current times, zero waste could be seen as impossible. However, some countries have already launched projects related to zero waste such as Australia, Netherlands and Sweden (Keller & Botkin, 2008).

World Food System and Composting:

Petroleum based world food system breaks all the biogeochemical cycles (water, carbon, nitrogen and phosphorus cycles) of the Gaia (earth system). Agriculture is the primary point of intersection between Gaia and human systems. However, agriculture also may be the best point of intervention. Therefore, it is important to approach agriculture as a holistic and living system. Some food movements already support this idea; organic farming, slow food, fair trade, composting etc. Composting is a very important step for creating a holistic system. Through composting process, waste is transformed into fertility. Agriculture must be approached as a living system not a receiving environment of chemical inputs. In the new food politics, human health, social justice and ecological sustainability are related to each other.

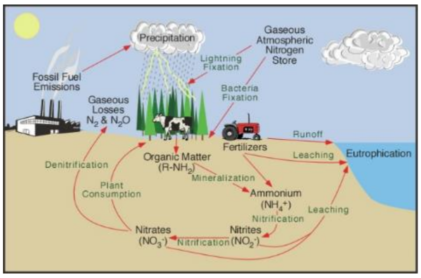
What is Compost?

Compost is decomposition of organic materials such as leaves, grass and food scraps. There are three types of composting which are backyard or home, vermicomposting and heat-based composting. Composting based on the fact that, invertebrates and microorganisms breakdown organic materials into a rich soil-like product. The four elements- carbon, nitrogen, air and water are essential for successful composting operation. Compost is a valuable product which can be used for soil amendment, mulch or even decontaminate natural habitats (EPA, 2002).

What can go into a composting bin?

Materials to include	Materials to exclude
Fruits and vegetables (green materials)	Meats
Tea bags	Dairy food
Coffee grounds with filter	Bones
Egg shells	Fats
Leaves (brown material)	Diseased plants
Wool and cotton rags (brown material)	Grease
Grass and yard chippings (brown material)	Oils (butter, mayonnaise etc...)
Sawdust (brown material)	Cooked meal
Paper (not bleached)	

Nitrogen Cycle and Composting



When the plants and animals die, decomposers (fungi, bacteria, protozoa, insects, worms, etc.) break the proteins into nitrogen (nitrate and ammonium) which can be reabsorbed by plants. Microorganisms play an important role by converting atmospheric nitrogen into plant available nitrogen. Gardeners use nitrogen cycle when doing compost. In a compost pile, the same microorganisms (bacteria, fungi, and protozoa) and invertebrates (worms and insects) in the soil break down the organic matter into proteins and amino acids. Then, the microorganisms break it down into nitrate and ammonium which can be taken up again by plants. Soil microorganisms regulate the release of plant available nitrogen from decomposing. Soil temperature also regulates decomposition process– the warmer the soil, the faster the decomposition.

3. ACTIVITY

3.1 COMPOSTING IN THE BACKYARD

- **In this study, you will observe composting process and take field notes until the end of the semester. <u>You are asked to make your observations and take notes individually.</u>**
- The steps in compost activity are :

1. First, choose a location for compost tumbler. The ideal location is shaded, close to water and close to kitchen.
2. Load the tumbler with green, nitrogen rich materials (green wastes)
3. Add brown, carbon rich materials (brown material)
4. Add some garden soil or finished compost that helps start decomposition process because soil or finished compost includes beneficial bacteria.
5. Close to compost tumbler and rotate it several times for mixing the materials
6. Add enough water to dampen the compost materials. The materials should not be wet.
7. Close and rotate tumbler again

3.2 GROWING YOUR OWN FOOD

- You will be a gardener while you are making compost. You will use old compost and plant some vegetables in the backyard. Your waste will be seeds and then food again. Thus, you will contribute to nutrient cycle in the earth.
- We will also try permaculture herb spiral. Herb spiral is a vertical sustainable garden which is located in a limited place in your garden. Herbs that thrive on drier soils live at the top, whereas those needing more moisture reside at the bottom where water collects. This form allows for planting of a widely diverse number of plants, and creates natural, sunny and shady areas — a perfect miniature microclimate landscape environment. The herb spiral as a permaculture form that allows you to create your own ecosystem and become self sufficient. Herb spiral is a good example of small sustainable system using water, soil, energy efficiently and it is a system working with nature in a harmnoy not against it (Permaculture garden, n.d).

Observations:

Write your observations in the compost pile and answer the questions below.

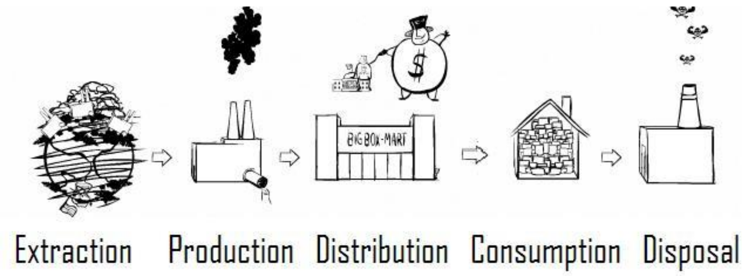
WEEKS	Color	Smell	Temperature	Compost appearance	Outdoor conditions	Observations about the garden
Week 1 25.04-2.05 2014						
Week 2 5.05-9.05 2014						
Week 3 12.05-16.05 2014						

Your inferences and conclusion based on your observations:

4. **DISCUSSION**

1. **Based on your observations and inferences in the course, how can you make relationship between <u>composting process</u>, <u>global natural cycles</u> (carbon, water, nitrogen) and <u>sustainability</u>? Please draw and explain.**

2.



Please compare the above human made system of producing and consuming goods with those of the natural cycles.

What is the difference? How the linear system may become a cycle? How can you transform your personal role in this system?

3. **As an evaluation of this outdoor exercise, please answer the following questions:**

   e. **What did you learn in this outdoor experience (consider two weeks)?**
   f. **What was the most interesting part for you?**
   g. **Whether your thinking about waste and soil system has changed or not? Please explain the reasons.**
   h. **Do you think about anything to be added, excluded, or changed related to the content, etc**

References:

Keller, E.A., and D.B. Botkin. 2008. Essential environmental science. Hoboken, NJ: John Wiley

Permaculture garden (n.d). Retrieved from http://www.realfarmacy.com/15-reasons-to-build an-herb-spiral-for-your- permaculture-garden/#E5cD6fPBYuSJOlPA.99

Sterling, S., Maiteny, P., Irving, D., & Salter, J. (2005). *Linking thinking: New perspectives on thinking and learning for sustainability*. Scotland, WWF.

Appendix E. RUBRICS

1.RUBRIC FOR EVALUATING SYSTEMS THINKING SKILLS

STS	MASTERY	DEVELOPING	EMERGING	PRE-AWARE
1.Identifying aspects of sustainability	Students clearly refer to more than two aspects of sustainability related to issue.	Students refer to two aspects of sustainability related to issue.	Students refer to one aspect of sustainability related to issue	Students do not refer to aspects of sustainability related to issue.
2. Seeing nature as a system	Students are able to look at the nature as a system considering most of the aspects of integral ecology and describe human-nature relationship in a holistic way	Students are able to look at the nature as a system considering two or three aspects of integral ecology and try to describe human-nature relationship in a holistic way.	Students struggle to look at the nature as a system and only consider one or two aspects of integral ecology and describe human-nature relationship from mechanistic perspective	No particular view of nature as a system
3. Identifying components of a system	Students are able to identify multiple components of a system in a clear way.	Students try to identify multiple components of a system.	Students are able identify one or two components of a system	Students can not identify components of a system.
4. Analyzing interconnections among the aspects sustainability	Students are able to critically analyze the interconnections among the components of a system by considering all aspects of sustainability.	Students are able to analyze interconnections by considering two aspects of sustainability.	Students struggle to analyze the interconnections among the aspects of sustainability.	Not analyzing the interconnections among the the aspects of sustainability

STS	MASTERY	DEVELOPING	EMERGING	PRE-AWARE
5. Recognizing hidden dimensions	Students are able to identify many hidden dimensions in a system by connecting to the issue clearly.	Students able to identify some hidden dimensions in a system and making connection to the issue in a simple way.	Students struggle to identify hidden dimensions in a system.	Students can not identify hidden dimensions in a system
6. Recognizing own responsbility in the system	Students are able to make connection between the problem/issue and their personal life.	Students try to make connection between the problem/ issue and their personal life	Students struggle to make connection between the problem/ issue and their personal life.	Students can not make any connection between the problem/issue and their personal life.
7. Considering the relationship between past, present and future	Students are able to make relationship between past, present and future clearly	Students try to make relationship between past, present and future. They mostly consider two time spans (e.g., past and present)	Students struggle to make relationship between past, present and future	Students can not make relationship between past, present and future
8. Recognizing cyclic nature of the system	Students are able to recognize cyclic nature of the system by giving examples (e.g., natural cycles)	Students try to recognize cyclic nature of the system in a simple way.	Students struggle to recognize cyclic nature of the system	No explanation about cyclic nature of the system

STS	MASTERY	DEVELOPING	EMERGING	PRE-AWARE
9. Developing empathy with other people	Students are able to develop empathy with other people by explaining their reasons or needs behind their actions without blaming them.	Students try develop empathy with other people, but they give simple explanations about their needs or reasons.	Students struggle to make empahty with other people. That is, they continue blaming them.	Students can not develop empathy with other people.
10. Developing empathy with non-human beings	Students are able to state their connection with non-human beings and to whole nature.	Students try to state their connection with non-human beings in a simple way.	Students struggle to make connection with non-human beings	Students can not make connection with the non-human beings.
11. Developing sense of place	Students are able to build multidimensional, holistic sense of place. They could attribute several meanings to the places (biophysical, social, cultural, political etc.)	Students try to build multidimensional sense of place. They could define the place as including two dimensions.	Students struggle to build multidimensional sense of place. They could define the place as including single dimension.	Students can not build any sense of place
12.Adapting ST perspective to personal life	Students are able to adapt systems thinking perspective to their personal life by taking transformative actions	Students almost start to adapt systems thinking perspective to their personal life by taking small steps.	Students struggle to adapt systems thinking perspective to their personal life. They describe simple actions for sustainability.	Student do not adapt systems thinking perspective to their personal life.

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2.RUBRIC FOR EVALUATING CONCEPT MAPS

Concept maps were used to evaluate the following systems thinking skills:

1. Identifying components and of a system and also connections among them (STS-3)
2. Recognizing hidden dimensions (STS-5)
3. Recognizing cycling nature of the system (ex. Relationships among natural cycles) (STS-8)

STS Level	Evaluation Criteria
MASTERY **(Complex)**	1. CM shows most of the components and connections in the system 2. CM shows most of the hidden dimensions clearly 3. CM shows cycling nature of the system (e.g., interconnections among the natural cycles if it is related to subject) (It depends on the subject) ❖ CM looks like a complex map
DEVELOPING **(Complex but still need to be developed)**	1. CM shows some of the components and connections in the system 2. CM shows some hidden dimensions 3. Some explanation about cycling nature of the system (e.g., a few interconnections among the natural cycles) ❖ CM almost looks like complex but needs to be developed
EMERGING **(Hiearcical, Linear)**	1. CM shows some components of the system but, connections are not clearly showed 2. CM does not show hidden dimensioms 3. A few explanation or no explanation about the cycling nature of the system ❖ CM almost looks like a linear and hierachical map

3.RUBRIC FOR EVALUATING LESSON PLANS

INSTRUCTIONAL COMPONENTS	EXEMPLARY	MAKING PROGRESS	NEEDS DEVELOPMENT
OBJECTIVES	The lesson plan reflects objectives related to more than two components of systems thinking skills	The lesson plan reflects objectives related to at least two components of systems thinking skills	The lesson plan does not reflect any objectives related to components of systems thinking skills
TEACHING PROCEDURE	The lesson plan includes activities in order to develop systems thinking skills of students and activities are consistent with all of the objectives	The lesson plan includes activities that address developing some systems thinking skills however, activities are explained indirectly and do not reflect consistency with some objectives	The lesson plan does not include any activities that focus on systems thinking skill development of students
ASSESSMENT	There is an intent to measure systems thinking skills of the students in a clear way	Try to measure several systems thinking skills of the students in a simple way	Not measuring systems thinking skills of the students

Appendix F: CODING BOOKLET

CODING BOOKLET FOR QUALITATIVE DATA ANALYSIS

STS	**Theme**	**Category**	**Rubric Levels**	**Definition of the THEMES**
STS-1: Identifying aspects of sustainability	Identifying aspects of Sustainability	Identifiying all aspects of sustainability (eg. Social, economical, environmental)	Mastery	Aspects of sustainability include environmental issues like water, waste, preservation of the ecosystem, social issues like employment, human rights, gender, equity, peace and economic issues like poverty reduction, corporating responsibility (UNESCO, 2005).
		Identifiying two aspects of sustainability (eg. Social and environmental)	Developing	
		Identifiying one aspect of sustainability (eg. environmental)	Emerging	
		No aspect of sustainability (not include a particular aspect)	Pre-aware	

STS	Theme	Category	Rubric Levels	Definition of the Themes and Categories
STS-2: Seeing Nature as a System	1.Integral Ecology	Identifying more than two aspects of integral ecology (eg. cultural, behavioral and experience)	Mastery	**Behavioral** aspect is related to more technical issues such as physical boundaries (eg. skin, cell memrans, tissues) or movements (eg. growth, digestion, flight, sleep) and measurements (eg. measurement of the PH in a river). **Cutlural** aspect refers to morals, symbols, system, meaning, affect etc. (eg. how human culture symbolize natural world). **Experience** aspects refers to subjective experiences such as social, emotional, spiritual (eg. personal experiences about a mountain). **Systems** aspect is related to interactions in the natural world (eg. food chain, migration etc.) and human effect in the world (eg. how economic development influences watershed dynamics) (Hargens, 2005).
		Identifying two aspects of integral ecology (eg. cultural and behavioral)	Developing	
		Identifying one aspect of integral ecology (eg. cultural)	Emerging	
		no aspect (no particular aspect of integral ecology)	Pre-aware	
	2.Human-Nature Relations hip	Holistic view	Mastery & Developing	Describing that nature is a living system and human is related to nature (Capra, 1999).
		Mechanistic View	Emerging	Describing a natural system in terms of human perspective as humankind is separated from nature and dominate to nature (Capra, 1999).
		No view	Pre-aware	There is not any particiular view in students' explanation.

STS	Theme	Category	Rubric Levels	Definition of the Themes and Categories
STS-3: Identifying components of a system	Components of a system	Multiple Components	Mastery & Developing	Components derived from the case. Multiple components include most of the components related to system, single component include one or two component and no component means that there is not any particular component described related to system.
		Single Component	Emerging	
		No Component	Pre-aware	
STS-4: Analyzing interconnections among the aspects sustainability	Interconnection among the aspects of sustainability	Interconnection among the all aspects of sustainability	Mastery	Interconnected relationship among the three aspects of sustainability (social, economic, environmental)
		Interconnection among the two aspects of sustainability	Developing	Interconnected relationships among the two aspects of sustainability (eg.environment and economy)
		Separated explanation	Emerging	Explaining the aspects of sustainability in a separated way.
		No interconnection	Pre-aware	No particular explanation of the interconnections
STS-5: Recognizing hidden dimensions	Hidden Dimensions in a system	Explaining hidden dimension/s	Mastery Developing Emerging	Recognizing patterns and interrelations that are not seen on the surface (Assaraf & Orion, 2010). This theme is evaluated based on the rubric levels. For instance, if individuals could explain many hidden dimensions in a system, they are evaluated in the category of explaining hidden dimensions.
		Not explaining any hidden dimension/s	Pre-aware	

STS	Theme	Category	Rubric Levels	Definition of the Themes and Categories
STS-6: Recognizing own responsbility in the system	Recognizing own responsibility	Stating the own responsibilities	Mastery Developing Emerging	Understanding personal role in the global problems/issues and taking responsibility for the choices we make (Sleurs, 2008; UNECE, 2011).
		Not stating own responsbilities	Pre-aware	
STS-7: Considering the relationship among past, present and future	Making connection among past, present and future	Making connection among three time spans (past, present and future)	Mastery	Critically analyzing and understanding past developments and the reasons of these developments in the context of sustainability aspects (UNECE, 2011). Creating visions for the future and considering the impact of today actions to the future and promoting individuals to make positive choices for sustainability (UNECE, 2011).
		Considering two time spans	Developing	
		Considering two time spans simply	Emerging	Explaining two time spans (eg. past and future) but not making connection among them.
		Considering one time span	Pre-aware	Explaining the only one particular time such as giving example from the present time not connecting to past or future.
STS-8: Recognizing cyclic nature of the system	Cyclic nature of the system	Explaining cycling nature of the system	Mastery Developing Emerging	Understanding that natural systems work in cycles which mean that there is not begining and end points (Kali et al., 2003).
		Not explaining cycling nature of the system	Pre-aware	

STS	Theme	Category	Rubric Levels	Definition of the Themes and Categories
STS-9: Developing empathy with other people	Empathy with people	Considering other people's perspective in a complete way	Mastery	Understanding other people' perspectives and their reasons behind their actions without blaming them (Sleurs, 2008; Sterling, 2005; UNECE, 2011)
		Considering other people' perspectives in a simple way	Developing	Understanding other people' perspectives and their reasons behind their actions, sometimes blaming the system.
		Considering other people's perspective in one side.	Emerging	Understanding the issue only from one side perspective (eg. considering local people only)
		No empathy with other people	Pre-aware	Not building empathy with other people.
STS-10: Developing empathy with non-human beings	Empathy with non-human beings	Considering non-human beings	Mastery-Developing -Emerging-	Related to feeling interconnectedness to non-human beings and to the nature (Sleurs, 2008).
		No empathy with non-human beings	Pre-aware	Not feeling interconnectedness to non-human beings and to the nature
STS-11: Developing sense of place	Sense of place	Multidimensional sense of place	Mastery & Developing	Multidimensional sense of place is related to Ardoin's (2006) four dimensional sense of place framework. These four dimensions are; biophysical environment, psychological element, sociocultural and political context.
		Singe dimensional sense of place	Emerging	Related to single dimensions of sense of place such as biopysical enviroment or psychological element (Ardoin, 2006; Moseley, et al., 2015)
		No sense of place	Pre-aware	There is not any descriptions related to sense of place.

STS	Theme	Category	Rubric Levels	Definition of the THEMES
STS-12: Adapting Systems thinking perspective to personal life	Personal actions for sustainability	Transformative actions for sustainability	Mastery & Developing	Actions having educational and transformative purpose, resulting in meaningful projects for sustainability (Sleurs, 2008)
		Simple actions for sustainability	Emerging	Integrating sustainable behaviors to the personal life by taking small steps like doing recycling.
		No action	Pre-aware	No personal actions for sustainability.

Appendix G: OUTLINE FOR PREPARING LESSON PLANS

CONTENT OF THE LECTURE:

You will prepare an lesson plan for elementary school students. The time of the lecture will be 2 or 3 hours.
The lesson plan will include the below components:

INTRODUCTION

1. Select a big idea from the elementary science education book.
You could choose any science subject.

2. Write your objectives. What do you want your students to achieve after this lecture?

TEACHING PROCEDURE

1. Explain your teaching procedure in detail and mention why you chose this method.
2. Your lecture will include an outdoor trip to a place, observation, measurements, any kinds of activities..
3. In your lecture try to give sustainability perspective. Think about your sustainability definition and dimensions of sustainability and how to integrate this concept to your course.
4. Also, you will try to teach students how to think in a systemic or holistic way through your lecture. Your lecture will include a systemic or holistic understanding.. (please ask me about this part of your course, I can give ideas, suggestions to your work!!)

ASSESSMENT

1. For the assessment part, you could prepare any kind of activity, reflection, discussion in order to understand whether the students obtained sustainability and system thinking perspective. Explain this part in detail!
    - Please be creative!
    - You dont need to find so many things. You can explain what you want to give your students with only one creative activity...It depends on you.
    - You can use internet, but dont copy an activity directly from the internet. Adapt the activity in accordance with system thinking and sustainability perspective. Or you can create your own activity!
    - Please give your references if necessary...
    - ❖ You will prepare the course <u>in pairs or individually. I</u>t depends on you.
    - ❖ The percentage of this HW is 30%

APPENDIX H: ETHICAL COMMITTEE APPROVAL OF METU

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APPLIED ETHICS RESEARCH CENTER

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Gönderen : Prof. Dr. Canan Özgen
IAK Başkanı

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz İlköğretim Bölümü öğrencisi Güliz Karaarslan'ın "Fen Bilgisi Öğretmenleri Sürdürülebilir Kalkınma Eğitmeni Olabilirler mi? Sınıf Dışında Sürdürülebilir Kalkınma İçin Eğitim Modeli" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

17/02/2014

Prof.Dr. Canan Özgen
Uygulamalı Etik Araştırma Merkezi
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APPENDIX I: TURKISH SUMMARY

GİRİŞ

Günümüzde bilimsel ve teknolojik gelişmeler insan yaşamını kolaylaştırırken pek çok küresel sorunu beraberinde getirmektedir. İklim değişikliği ve biyolojik çeşitlilik örneğinde olduğu gibi, küresel sorunlar hem karmaşık hem de birbiriyle oldukça ilişkilidir (Sterling, 2010). Son yıllarda yapılan araştırmalarda sürdürülebilir bir gelecek için sorumlu bireyler yetiştirmek amacıyla fen eğitimi ile sürdürülebilirlik için eğitim (SiE) arasındaki etkileşimin geliştirilmesi önemle vurgulanmaktadır (Stratton, Hagevik, Feldman & Bloom, 2015). Fen eğitimi araştırmacıları karmaşık ve çok boyutlu küresel problemlerin çözümüne destek sağlamak amacı ile etik, ahlak ve sürdürülebilirlik gibi kavramları da göz önünde bulundurularak fen eğitiminin yeniden yapılandırılması gerektiğini öne sürmüşlerdir (örn., Carter, 2008; Colucci-Gray, Perazzone, Dodman & Camino, 2013; Feldman & Nation, 2015; Gough, 2008). Örneğin, Carter (2008) 21. yüzyılda fen eğitiminin öğrencilere bilimle ilgili kritik eleştiriler yapabilmeleri, dünyada daha adil, eşit ve sürdürülebilir bir yaşam için katılımcı olmalarını öğretmesinin gerekli olduğunu ileri sürmüştür. Bu yüzden fen bilgisi öğretmenleri sürdürülebilirlik okur yazarı olarak yetiştirilmeli (Carney, 2011; Foley, Archambault & Warren, 2015) yani fen bilgisi öğretmenleri öğrencilerini sürdürülebilir bir dünyaya hazırlamak için gerekli bilgi ve beceriye sahip olmaları gereği öne sürülmektedir (Stratton et al., 2015). Gelecek nesilleri şekillendiren öğretmenlerin özellikle SiE alanında gerekli yeterliliklere sahip olması gerektiği çeşitli uluslararası raporlarda da vurgulanmaktadır (örn., UNECE, 2011; Sleurs, 2008). Dolayısı ile, bu doktora tezi çalışması fen bilgisi öğretmenlerinin SiE eğitmeni olarak yetiştirilmesi üzerine odaklanmaktadır. Alan yazınında yeterlilik kavramı sürdürülebilirliğin öğretilmesi ve öğrenilmesinde dönüm noktası olarak ifade edilmektedir (Wals, 2010; Wiek, Withycombe & Redman, 2011; UNECE, 2011). Bu çalışmada yeterlilik kavramı karmaşık, çok yapılı, hem bilişsel hem de duyuşssal becerileri içine alan bir kavram olarak ele alınmıştır (örn., Sleurs, 2008; Strachan, 2012; UNECE, 2011). Son yıllarda özellikle yükseöğretimde sürdürülebilirliği öğretmen eğitimi programlarına entegre etmek için çalışmalar yürütülmektedir. Örneğin, Amerika Birleşik Devletleri'nde hazırlanan ulusal bir raporda öğrencileri sürdürülebilir bir geleceğe hazırlamak için öğretmenlerin sahip olması gereken yeterliliklerden bahsedilmiştir (Washington State OSPI, 2008). Aynı zamanda Birleşmiş Milletler Avrupa Ekonomi Komisyonu (UNECE, 2011) tüm eğitim sektöründe SiE ile ilgili temel yeterliliklerin belirlenmesi gerektiğini vurgulamıştır. SiE 21. yüzyılın inkar edilemez bir gerekliliğidir ve fen bilgisi öğretmenlerinin sosyal, çevresel, ekonomik, kültürel çok boyutlu, karmaşık problemleri anlamak ve öğrencileri gelecekte bu problemlerin çözümünde karar vericiler olarak yetiştirmek için SiE alanındaki yeterliliklere sahip olması gerekmektedir. Bu yeterlilikler arasında özellikle vurgulanan sistemsel düşünme becerileridir ve öğretmenlerin bu beceriyi kazanmaları önem taşımaktadır.

1.1 Sistemsel Düşünme ve Kuramsal Çerçeve

Sistemsel düşünme, karmaşık sistemlerin bileşenlerinin, bunlar arasındaki ilişkilerin, örüntülerin anlaşılmasını, büyük resmin görülmesini sağlayan 21. yüzyılın karmaşık sorunlarıyla başedebilmek için yeni bir düşünme yöntemi olarak ifade edilmektedir (Capra & Luisi, 2014). Sistem düşüncesi özellikle 19. yüzyılın Newton-Kartezyen düşüncesinin etkisi kaybetmesi ve dünyanın mekanik değil yaşayan, karmaşık bir sistem olarak kabul edilmesiyle birlikte ilk defa biyoloji alanında ortaya atılmıştır (Capra & Luisi, 2014). Daha sonra mühendislik, fizik, psikoloji, ekonomi ve eğitim alanlarında da önem kazanmıştır (Sleurs, 2008). Fen eğitimi alanında da sistemsel düşünme ile ilgili pek çok çalışma yapılmaktadır. Örneğin, Assaraf ve Orion (2005) özellikle yer bilimleri alanında sistemsel düşünme becerileri üzerine çalışmışlar ve sistemsel düşünmenin sekiz karakteristiğini belirlemişlerdir. Bunlardan bazıları şöyledir: Bir sistemin bileşenlerini ve onlar arasındaki ilişkileri belirleyebilmek, sistem içerisindeki gizli bileşenleri fark edebilmek ya da sistemin döngüsel doğasını fark etmek. SiE alanında da sistemsel düşünme önemli bir bileşen olarak yer almaktadır. Örneğin, Nolet (2009) sistemsel düşünmeyi sürdürülebilirlik okuryazarlığının bir bileşeni olarak ele almıştır ve bu kavramı sosyal, ekonomik ve çevresel sistemler arasındaki ilişkileri kavramak olarak tanımlamıştır. Ayrıca sistemsel düşünme SiE alanında öğretmenler ve eğitimcilerin sahip olmaları gereken temel yeterliliklerden biri olarak tanımlanmıştır (Sleurs, 2008; UNECE, 2011). Temel olarak bu doktora tezinde fen eğitimi ve SiE alanında literatürden faydalanarak (örn., Assaraf & Orion, 2005; UNECE, 2011) 12 sistemsel düşünme becerisi belirlenmiştir. Ayrıca fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini geliştirmek için açık alanda SiE modeli önerilmiştir. Açık alanda eğitim kompleks sistemleri ve onları arasındaki ilişkileri anlamak ve bireylerin sürdürülebilirlik okur yazarlığını geliştirmek, geniş bir perspektiften bakabilmelerini sağlamak için zengin bir öğrenme ortamı sağlar (Beames et al., 2012; Hill, 2012; Lugg, 2007). Aynı zamanda alan yazınındaki çalışmalara göre açık alanda eğitim bireylerin sistemsel düşünme becerilerini geliştirmede de önemli rol oynar (örn., Assaraf & Orion, 2005, 2010b).

1.2 Çalışmanın Amacı ve Araştırma Soruları

Yukarıda özetlenen alan yazını kapsamında bu doktora tezi fen bilgisi öğretmenlerini SiE eğitmeni olarak yetiştirebilmek için sistemsel düşünme becerilerini geliştirilmesini amaçlamaktadır. Araştırma soruları öncelikle fen eğitimi ve SiE alanındaki yeterliliklerin karşılaştırılması, sistemsel düşünme becerilerinin ölçülebilmesi için ölçeklerin belirlenmesi, geçerlilik ve güvenirliğinin sağlanması, fen bilgisi öğretmen adaylarının sistemsel düşünme beceri düzeylerinin belirlenmesi, sistemsel düşünme becerilerinin açık alanda SiE ile nasıl geliştirilebileceğinin araştırılması ve son olarak fen bilgisi öğretmen adaylarının gelecekte kendi öğrencilerinin sistemsel düşünme becerilerini nasıl geliştirebileceği üzerine ders planlarının incelenmesi olarak kurgulanmıştır. Araştırma soruları aşağıda sırayla sunulmaktadır:

1. Fen bilgisi öğretmenlerinin sürdürülebilirlik için eğitim eğitmeni olabilmeleri için gerekli yeterlilikler nelerdir?
2. Fen bilgisi öğretmenlerinin sürdürülebilirlik için eğitim eğitmeni olabilmeleri için gerekli bir yeterlilik olan sistemsel düşünme becerileri nasıl ölçülebilir?
3. Sistemsel düşünme becerilerini ölçmek için geliştirilen ölçeklerin geçerlilik ve güvenirliği nedir?
4. Fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerilerinin düzeyi nedir?
5. Açık alanda sürdürülebilirlik için eğitim dersiyle fen bilgisi öğretmen adaylarının sistemsel düşünme becerileri nasıl geliştirilebilir?
6. Fen bilgisi öğretmen adayları sistemsel düşünme becerilerini açık alanda sürdürülebilirlik için eğitim dersi kapsamında ders planlarına ne ölçüde yansıtabililer?

YÖNTEM

Bu çalışma beş aşamada uygulanmıştır. Bunlar, fark analizi, sistemsel düşünce becerilerinin ölçülmesi için ölçeklerin geliştirilmesi, açık alanda SiE dersinin tasarlanması, pilot çalışma ve ana çalışmadır.

İlk olarak fen bilgisi öğretmenleri ve SiE eğitim eğitmenlerinin yeterliliklerini karşılaştırmak amacıyla teorik ve uygulamalı olmak üzere iki bölümden oluşan fark analizi yöntemi uygulanmıştır. Teorik bölümde fen bilgisi öğretmenleri ve SiE eğitmenlerinin yeterlilikleri ilgili alan yazınını incelenmiştir (örn., Nezvalova, 2007; NSTA, 2012; MoNE, 2008; UNECE, 2011). Daha sonra beş fen bilgisi eğitimi ve SiE alanlarında çalışan araştırmacılarla görüşmeler yapılmıştır. Fark analizi yöntemi sonuçlarına göre sistemsel düşünme fen bilgisi öğretmenlerinin SiE eğitmeni olabilmeleri için gerekli olduğu belirlenmiştir.

İkinci aşamada fen eğitimi ve SiE alanında 12 sistemsel düşünme becerileri tanımlanmış ve bu becerilerin ölçülmesi amacı ile nitel ölçme araçları (deneme yazımı, durum analizi, görüşmeler, kavram haritaları ve gezi raporları) geliştirilmiştir. Fen Eğitimi ve SiE alanında belirlenen sistemsel düşünme becerileri Tablo 1'de verilmektedir.

Tablo 1.
Fen Eğitimi ve SiE Alanında Sistemsel Düşünme Becerileri

	Sistemsel Düşünme Becerileri (SDB)
SDB-1	Sürdürülebilirliğin boyutlarını belirleyebilmek
SDB-2	Doğayı bir sistem olarak görebilmek
SDB-3	Bir sistemin bileşenlerini belirleyebilmek
SDB-4	Sürdürülebilirliğin boyutları arasındaki ilişkileri analiz edebilmek
SDB-5	Gizli bileşenleri fark edebilmek
SDB-6	Sistemde kendi sorumluğunun farkına varabilmek
SDB-7	Geçmiş, gelecek ve günümüz arasındaki ilişkiyi fark edebilmek
SDB-8	Sistemin döngüsel doğasını fark edebilmek
SDB-9	Diğer kişilerle empati kurabilmek
SDB-10	Diğer canlılarla empati kurabilmek
SDB-11	Mekan algısı geliştirebilmek
SDB-12	Sistemsel düşünme perspektifini kendi yaşamına uyarlayabilmek

Üçüncü aşamada ise fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini geliştirmek amacıyla açık alanda SiE dersi tasarlanmıştır.

Çalışmanın pilot denemesinin yapıldığı dördüncü aşamada daha önce geliştirilen ölçme araçları test edilmiş ve fen bilgisi öğretmenlerinin mevcut sistemsel düşünme becerileri belirlenmiş ve açık alanda SiE dersinin pilot uygulaması gerçekleştirilmiştir.

Son olarak, ana çalışmada fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini geliştirmek için açık alanda SiE dersi uygulanmıştır.

Açık alanda SiE dersi üç bölümden oluşmaktadır: İki haftalık süreçten oluşan birinci bölümde derse katılan sekiz fen bilgisi öğretmen adayının dersin başında mevcut sistemsel düşünme becerilerinin belirlemek için nitel ölçme araçları ile (deneme yazımı, durum analizi ve görüşmeler) veriler toplanmıştır. Dersin ikinci bölümü ise beş haftalık programdan oluşmaktadır. Bu aşamada sistemsel düşünme becerilerinin geliştirilmesi: Bir sistemin sürdürülebilir kullanımı nedir? Başlığı altından Eymir Gölü'nde alan gezileri düzenlenmiştir. Eymir Gölü'nde orman ekosistemi araştırılması, su kalitesi ölçümleri ve insan kullanımları üzerine gözlemler yapılmış ve veriler toplanmıştır. Dersin son bölümü ise dört haftalık programdan oluşmaktadır. Sistemsel düşünme becerilerinin geliştirilmesi: Sürdürülebilir çözümler başlığı altında öğretmen adaylarıyla birlikte kompost ve bahçe uygulamaları gerçekleştirilmiştir. Ders süresince derse katılan sekiz fen bilgisi öğretmen adayından dersin başında, ortasında ve sonunda olmak üzere nitel ölçme araçları kullanılarak (deneme yazımı, durum çalışması, görüşmeler, gezi raporları ve kavram haritaları) veriler toplanmıştır. Verilerin analizinde nitel veri analizi yöntemleri kullanılmıştır. Sistemsel düşünme becerilerine göre tema ve kategoriler önceden belirlenmiş ve analiz süresince ortaya çıkan yeni kategorilerin de eklenmesiyle kod tablosu oluşturulmuştur (EK-F). Fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin profili daha önce değerlendirme tablosunda tanımlanan dört kategoriye göre belirlenmiştir (EK-E). Kategoriler sırasıyla *yeterli, gelişmekte olan, yeni ortaya çıkan ve farkındalık öncesi* olan adlandırılmıştır. Örneğin, SDB-1 “Sürdürülebilirliğin boyutlarını belirleyebilmek” (SDB-1) için sürdürülebilirliğin boyutlarından ikiden fazlasına değinen katılımcıların sistemsel düşünme becerisi yeterli, iki boyuta (örn., çevresel ve sosyal) değinenlerin gelişmekte olan, sadece bir boyutuna (örn. çevresel) yer verenlerin yeni ortaya çıkan ve sürdürülebilirliğin boyutlarından hiç bahsetmeyenlerin ise sistemsel düşünme becerisinin düzeyi farkındalık öncesi olarak belirlenmiştir. SDB-1 için daha önceden belirlenen tema sürdürülebilirliğin boyutlarını tanımlamak ve kategoriler ise sürdürülebilirliğin tüm boyutlarını belirlemek, sürdürülebilirliğin iki boyutunu belirlemek, sürdürülebilirliğin tek boyunu belirlemek ve sürdürülebilirliğin hiç bir boyutunu belirlememek olarak ifade edilmiştir (EK-F). Kavram haritaları ise “Bir sistemin bileşenlerini belirleyebilmek (SDB-3), Gizli bileşenleri fark edebilmek (SDB-5) ve Sistemin döngüsel doğasını fark edebilmek (SDB-8)” olmak üzere üç sistemsel düşünme becerisini ölçmüştür. Sistemsel düşünme becerilerinin profili kavram haritalarının değerlendirilmesi için hazırlanan değerlendirme tablosuna göre belirlenmiştir (EK-E). Bir sistemin bileşenleri, bileşenler arasındaki ilişkiler, ilişkilerin karmaşıklığı ve hiyerarşik olup olmamasına göre kavram haritaları analiz edilmiştir. Ders planlarının nitel analizi ise aynı şekilde ders planlarının değerlendirilmesi için hazırlanan değerlendirme tablosuna göre yapılmıştır. Kazanımlar, öğretim metotları ve değerlendirme olmak üzere üç bölüm ayrı ayrı değerlendirme kategorilerine göre değerlendirilmiştir (Ek-E). Tüm verilerin içinden rastlantısal olarak seçilen örneklemler başka bir araştırmacı tarafından analizi edilerek verilerin puanlayıcılar arası güvenirliği de sağlanmıştır. Nitel veri analizinin geçerliliğinin sağlanması için çeşitli kaynaklardan veri toplanmıştır (durum analizi, gezi raporları, görüşmeler vd.) ve bu veri toplama araçlarının verdiği sonuçlar karşılaştırılmıştır. Aynı zamanda sistemsel düşünme becerilerinin geliştirilmesi ve ölçeklerin hazırlanmasında SiE alanında uzman iki kişinin görüşleri de alınmıştır. Sonuç olarak fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin belirlenmesi ve geliştirilmesine açık alanda SiE dersi uygulanmış ve çeşitli veri toplama araçlarından veriler toplanarak araştırmacı tarafından oluşturulan kod tablosu ve değerlendirme tabloları yardımıyla analiz edilmiştir.

BULGULAR

Bulgular üç aşamada sunulmaktadır. İlk olarak fark analizinin sonuçları, daha sonra pilot çalışma sonuçları ve son olarak ana çalışmanın sonuçları verilmektedir.

3.1 Fark Analizi Sonuçları:

Fen bilgisi öğretmen adaylarının yeterlilikleri ve SiE eğitmenlerinin yeterlilikleri arasındaki farkları tespit etmek için öncelikle yazım alanı taraması yapılmıştır. Fen bilgisi öğretmen adaylarının sahip olması gereken yeterlilikleri belirlemek amacıyla çeşitli raporlar incelenmiştir. Bunlardan bazıları ulusal Amerika'daki fen bilgisi öğretmenleri birliğinin 2012 raporu (NSTA, 2012) ve diğeri yine Amerika'daki Ulusal araştırma konseyinin fen eğitimi için hazırladığı yenilikçi yaklaşımların yer aldığı rapordur (NRC, 2012). Türkiye'den ise Milli Eğitim Bakanlığı tarafından hazırlanan fen bilgisi öğretmenleri için özel alan yeterlilikleri raporu incelenmiştir (MoNE, 2008). SiE eğitmenlerinin sahip olması gereken yeterlilikler için ise Avrupa Ekonomi Komisyonu'nun hazırladığı SiE alanında yeterlilikler isimli raporu incelenmiştir (UNECE, 2011). Yazın alanı taramasında fen bilgisi öğretmenlerinin sahip olması gereken yeterlilikler arasında SiE eğitmenlerinin sahip olması gereken yeterliliklerin herhangi birine rastlanmamıştır. Örneğin, bütüncül yaklaşım, çevre, ekonomi, toplum arasındaki ilişkilerin fark edilmesi, farklı grupları, kültürleri anlamak, empatik ilişkiler kurmak gibi yeterlilikler fen bilgisi öğretmenlerinin sahip olması gereken yeterliliklerde yer almamaktadır. Özellikle sistemsel düşünme hem fen bilgisi eğitiminde hem de SiE'de önemli bir yeterlilik olarak yer almaktadır (Assaraf & Orion, 2010; Batzri ve diğerleri, 2015). Bu nedenle yazın alanı taraması sonucunda sistemsel düşünmenin fen bilgisi öğretmenlerinin SiE eğitmeni olabilmeleri için sahip olmaları gereken önemli yeterliliklerden biri olduğu tespit edilmiştir.

Fark analizinin ikinci aşamasında ise fen bilgisi eğitimi ve SiE alanında çalışan beş araştırmacı (doktora öğrencileri) ile görüşmeler yapılmıştır. Görüşme sonuçları da yazın alanı taramasını desteklemektedir. Araştırmacıların hepsi fen bilgisi öğretmenlerinin bütüncül bir yaklaşımı benimsemeleri gerektiğini ifade etmişlerdir. Sonuç olarak sistemsel düşünme 21. yüzyılda hem SiE alanında hem de fen bilgisi eğitiminde önemli bir yeterlilik olarak göze çarpmaktadır.

3.2 Pilot Çalışma Sonuçları

Pilot çalışma, geliştirilen nitel ölçeklerin test edilmesi, geçerlilik ve güvenirliğin belirlenmesi, açık alan gezilerinin uygulanması ve fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerilerinin tespit edilmesi amacıyla uygulanmıştır. Pilot çalışmanın verileri deneme yazımı, durum analizi, görüşmeler, gezi raporları ve kavram haritaları aracılığıyla toplanmıştır. Her bir ölçek farklı sistemsel düşünme becerilerini ölçmektedir. Örneğin, deneme yazımı ile öğretmen adaylarında "Bir ağaç sizin ne ifade ediyor?" ya da "Bir göl sizin için ne ifade ediyor?" soruları sorularak öğretmen adaylarının doğayı bir sistem olarak görebilme (SDB-2) becerisi ölçülmüştür. Durum analizi ölçekleri ise üç farklı sistemsel düşünme becerisini ölçmektedir. Bunlar, sürdürülebilirliğin boyutlarını belirleyebilmek (SDB-1), bir sistemin bileşenlerini belirleyebilmek (SDB-3) ve sürdürülebilirliğin boyutları arasındaki ilişkileri analiz edebilmektir (SDB-4). Görüşmeler yoluyla Tablo-1'de verilen on iki sistemsel düşünme becerisi ölçülebilmektedir.

Özet olarak, pilot çalışma sonuçları fen bilgisi eğitimi ve SiE alanında belirlenen sistemsel düşünme becerilerinin yukarıda ifade edilen nitel ölçme araçlarıyla ölçülebileceğini göstermiştir. Aynı zamanda bu ölçme araçları ile belirlenen fen bilgisi öğretmen adaylarının sistemsel düşünme becerileri genellikle düşük kategorilerde bulunmuştur (*yeni ortaya çıkan ve farkındalık öncesi*). Ayrıca pilot çalışma sırasında uygulanan iki açık alanda eğitim etkinliği ile (Eymir Gölü gezisi ve atıkların dönüştürülmesi) fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini geliştirmelerine katkıda bulunduğu tespit edilmiştir. Örneğin, alan gezileri öğretmen adaylarının doğayı bir sistem olarak görebilmek, insan-doğa ilişkisini kavrayabilmek ve doğanın döngüsel sistemini fark edebilmek gibi becerilerin gelişimine katkıda bulunmaktadır. Ders sırasından öğretmen adaylarına çizdirilen kavram haritaları da çeşitli sistemsel düşünme becerilerinin ölçülmesine yardımcı olmuştur. Bunlar; bir sistemdeki bileşenleri ve bağlantıları belirleyebilmek, bir sistemdeki gizli bileşenleri ve doğal sistemlerin karmaşıklığını fark edebilmektir.

3.2.1 Pilot Çalışmadan Çıkarılan Dersler

Pilot çalışma sonucunda geliştirilen nitel ölçme araçları ile farklı sistemsel düşünme becerilerinin ölçülebileceği anlaşılmıştır. Pilot çalışmada gerçekleştirilen ilk görüşmelerle öğretmen adaylarının yazdıkları denemeler ve durum analizinde verdikleri yanıtlarla ilgili daha detaylı bilgi alınması sağlanmıştır. İkinci görüşme ise alan gezileri üzerinden hazırlanan sorularla gerçekleştirilmiştir. Görüşmeler sonucunda 12 sistemsel düşünme becerisinin ölçülebileceği kanıtlanmıştır. Aynı zamanda gezi raporlarının da önemli bir ölçme aracı olabileceği belirlenmiştir. Bazı katılımcılar gezi raporlarındaki sorulara detaylı yanıtlar vermişlerdir. Pilot çalışma sonucunda araştırmacı tüm ölçme araçlarını ana çalışmada kullanmaya karar vermiştir. Ancak bazı sorular ile ilgili değişiklikler yapılmıştır. Örneğin, durum analizi için çok boyutlu, daha karmaşık sürdürülebilirlikle ilgili konular seçilmiştir. Aynı zamanda alan gezilerinin de kapsamı ve süresi genişletilmiştir. Örneğin, Eymir gezisi üç hafta açık alanda eğitim ve bir hafta sınıfta tartışma haftası olarak hazırlanmıştır. Üç haftalık süreçte fen bilgisi öğretmen adaylarına Eymir'i farklı açılardan inceleme olanağı verilmiştir. İlk hafta Eymir'de orman ekosistemi araştırması, ikinci hafta su kalitesi ölçümleri ve üçüncü hafta ise insan kullanımlarının araştırılması ile ilgilidir. Böylece öğretmen adaylarının Eymir'i çevresel, sosyal ve ekonomik açılardan çok boyutlu bir doğal sistem olarak görmeleri hedeflenmiştir.

Pilot çalışma sonucunda sistemsel düşünme becerilerini değerlendirmek için geliştirilen değerlendirme tablosunda da bazı değişiklikler yapılmıştır. Tablo daha önce üç kategoriden *(yeterli, gelişmekte olan ve yeni ortaya çıkan)* oluşurken sistemsel düşünme becerilerini daha iyi değerlendirmek ve güvenilir sonuçlar elde edebilmek için bir kategori daha eklenmiştir. Böylece değerlendirme tablosu *yeterli, gelişmekte olan, yeni ortaya çıkan ve farkındalık öncesi* olmak üzere dört kategoriden oluşmuştur.

Pilot çalışmaya 29 katılımcı katılmıştır. Ana çalışmada ise fen bilgisi öğretmen adaylarının sistemsel düşünme profilini ortaya çıkarmak için daha az kişi ile çalışmaya karar verilmiştir ve sekiz fen bilgisi öğretmen adayı yer almıştır. Ana çalışmada tekli gömülü durum analizi yöntemi benimsenerek, sistemsel düşünme becerileri birim analizi olarak ele alınmıştır.

Pilot çalışmadan elde edilen diğer bir sonuç ise fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerileridir. Pilot çalışma sonucunda katılımcıların sistemsel düşünme becerileri yeterli düzeyde bulunmamıştır. Örneğin, katılımcılar kapsamlı, çok boyutlu bir sürdürülebilirlik bakış açısına sahip değillerdir. Olayları değerlendirirken geçmiş, gelecek ve günümüz arasında bağlantı kurmakta, empati geliştirmekte ve mekan algısı oluşturmakta zorlanmışlardır. Bu nedenle fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin geliştirilmesi gerektiği sonucuna varılmıştır.

3.3 Ana Çalışma Sonuçları

Ana çalışma fark analizi ve pilot çalışma sonuçlarına göre tasarlanmıştır. Ana çalışmada iki araştırma sorusuna cevap aranmıştır. Bunlar; "Açık alanda aürdürülebilirlik için eğitim dersiyle fen bilgisi öğretmen adaylarının sistemsel düşünme becerileri nasıl geliştirilebilir?" ve "Fen bilgisi öğretmen adayları sistemsel düşünme becerilerini açık alanda sürdürülebilirlik için eğitim dersi kapsamında ders Planlarına ne ölçüde yansıtabililer?”

3.3.1 Araştırma Sorusu-5: Açık Alanda Sürdürülebilirlik için Eğitim Dersiyle Fen Bilgisi Öğretmen Adaylarının Sistemsel Düşünme Becerileri Nasıl Geliştirilebilir?

Fen bilgisi öğretmen adaylarının sistemsel düşünme becerileri açık alanda SiE dersi boyunca üç bölüm ile ölçülmüştür. Birinci bölümde deneme yazımı, durum analizi ve görüşmeler yoluyla ders başlamadan önce katılımcıların mevcut sistemsel düşünme becerileri belirlenmiştir. İkinci ve üçüncü bölümlerde ise katılımcıların sistemsel düşünme becerilerindeki gelişim yine deneme yazımı, durum analizi, görüşmeler, gezi raporları ve kavram haritaları kullanılarak araştırılmıştır. Bu sayede ders süresince katılımcıların sistemsel düşünme becerilerini nasıl geliştirdikleri tespit edilmiştir.

3.3.1.1 Mevcut Sistemsel Düşünme Becerilerinin Belirlenmesi (Bölüm -I)

Fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerileri deneme yazımı, durum analizi ve görüşmeler aracılı ile ölçülmüştür. Deneme yazımı ve durum analizi sonuçları görüşmelerle benzer sonuçlar vererek sonuçlar birbirini desteklemiştir. Analiz sonuçlarına göre fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinden Sürdürülebilirliğin boyutlarını belirleyebilmek (SBD-1), Doğayı bir sistem olarak görebilmek (SDB-2) ve Bir sistemin bileşenlerini belirleyebilmek (SDB-3) *yeni ortaya çıkan ve gelişmekte* olan kategorilerinde değerlendirilmiştir. Fen bilgisi öğretmen adayları başlangıçta bu becerilere belli oranda sahiplerdir. Ancak SDB-3’den sonra diğer becerilerin daha düşük düzeylerde olduğu tespit edilmiştir. Örneğin, sürdürülebilirliğin boyutları arasındaki ilişkileri analiz edebilme (SDB-4) becerisi için bir katılımcı farkındalık öncesi, altı katılımcı yeni ortaya çıkan ve bir katılımcı gelişmekte olan kategorilerinde değerlendirilmiştir. Katılımcıların çoğu sürdürülebilirliği tek bir boyutta yani genellikle çevre boyutunda değerlendirmekte ve diğer boyutları arasındaki ilişkileri analiz etmekte zorluk yaşamaktadırlar. Örneğin, bir katılımcının açıklaması bağlantı kuramamak kategorisinde ve *farkındalık öncesi* düzeyinde bulunmuştur. Katılımcının açıklaması şöyledir:

> PST-5: Havaalanını o alana kurmak yerine, daha verimsiz bir bölgeye kurabilirler. Bu şekilde doğal dengeyi koruyabilirler.

Sürdürülebilirliğin iki boyutu arasında ilişki kurabilen ve gelişmekte olan düzeyinde değerlendirilen bir katılımcı ise görüşmede şöyle söylemiştir:

> PST-3: Evet havaalanına ihtiyacımız var. Fakat havaalanını doğaya zarar vermeyecek şekilde en uygun yere kurmalıyız. Doğaya ve insanlara zarar vermeyecek şekilde bunu yapmamız gerekiyor.

Diğer sistemsel düşünme becerileri (örn., gizli bileşenleri fark edebilmek, sistemde kendi sorumluğunun farkına varabilmek) için katılımcıların çoğu farkındalık öncesi düzeyinde bulunmuşlardır. Aşağıdaki tabloda bazı sistemsel düşünme becerileri için temalar, kategoriler ve örnek maddeler sunulmaktadır.

Tablo-1.
Fen bilgisi öğretmen adaylarının görüşme sorularına göre mevcut sistemsel düşünme becerileri (temalar, kategoriler ve örnek maddeler

	Tema ve Kategoriler	Katılımcılar	Örnek Maddeler	Düzey
SDB-5: Gizli bileşenleri farkedebilmek	**Gizli bileşenleri farkedebilmek (SDB-5)** **a. Gizli bileşenleri açıklayabilmek (örn., Iklim değişikliği)**	PST-1 PST-2 PST-8	PST-2: Pek çok gizli bileşen var. Örneğin, bir havalanında pek çok uçak CO_2 salıyor ve iklim değişikliğine katkıda bulunuyor. Aynı zamanda, karbon tutan kaynakları yok ediyoruz (ağaçlar gibi) ve atmosferdeki CO_2 seviyesini artıyoruz.	Gelişmekte olan
	a. Gizli bileşenleri açıklayabilmek	PST-3 PST-6	PST-6: Orada yaşayan ağaçlar var, pek çok tür var. Ağaçları keserek iklim değişikliğine sebep oluyoruz ve oradaki türlerin yok olmasına…	Yeni ortaya çıkan
	b.Gizli bileşenleri açıklayamamak	PST-4 PST-5 PST-7	PST-7: Bu sorun sadece doğayla ilgili değil, orada yaşayan insanlarla da ilgili.	Farkındalık öncesi

Görüşme sonuçlarına göre bazı beceriler arasında karmaşık, hiyerarşik bir ilişki olabileceği tespit edilmiştir. Bazı beceriler için (örn., SDB-7, SDB-8, SDB-11) katılımcıların sistemsel düşünme becerisi *yeni ortaya çıkan yada farkındalık öncesi* olmak üzere düşük düzeylerde bulunmuştur. Aynı zamanda katılımcılar arasında bireysel farklılıklar olduğu da belirlenmiştir. Bazı katılımcılar bazı becerilere (örn., SDB-1, SDB-3) önceden belli düzeyde sahip iken bazı katılımcıların bu becerilere sahip olmadığı anlaşılmıştır.

3.3.1.2 Sistemsel Düşünme Becerilerinin Geliştirilmesi-Bölüm II ve III

Fen bilgisi öğretmen adaylarının sistemsel düşünme becerileri *Bir sistemin sürdürülebilir kullanımı ve sürdürülebilirlikle ilgili çözümler* başlıkları altında hazırlanan açık alanda SiE dersi kapsamında geliştirmeleri beklenmiştir. Ders süresince dersin ortasında ve sonunda görüşmeler, gezi raporları, kavram haritaları ve dersin sonunda uygulanan durum analizi ile nitel veriler toplanmıştır. Bölüm-2'de Eymir gezilerinden oluşan bölümü, Bölüm-3 ise kompost ve bahçe yapımı ile ilgili bölümü oluşturmaktadır.

3.3.1.2.1 Sistemsel Düşünme Becerilerinin Geliştirilmesi-Bölüm II

Bölüm II üç hafta alan gezisi ve iki hafta sınıf içi etkinliklerden oluşmaktadır. Bu bölümün sonunda görüşmeler, gezi raporları ve kavram haritaları kullanılarak katılımcıların sistemsel düşünme becerileri ölçülmüştür. Ders süresince katılımcılar üç gezi raporu hazırladılar ve Eymir'le ilgili bir kavram haritası çizdiler. Veri analizi sonuçlarına göre öğretmen adaylarının bazı becerileri geliştirdikleri ve değerlendirme tablosuna göre yüksek düzeyde oldukları tespit edilmiştir. Örneğin, sürdürülebilirliğin boyutlarını belirleyebilmek (SDB-1) becerisi için görüşme analizi sonuçlarına göre katılımcıların üçü *yeterli* ve beşi *gelişmekte olan* düzeylerinde bulunmuşlardır. Doğayı bir sistem olarak görebilmek (SDB-2) becerisi tüm katılımcılar için *yeterli* düzeyde bulunmuştu

Tablo 2.
Fen Bilgisi Öğretmen adaylarının görüşme sorularına göre sistemsel düşünme becerileri-Bölüm-II (temalar, kategoriler ve örnek maddeler)

	Tema ve Kategoriler	Katılımcılar	Örnek Maddeler	Rubrik Düzeyi
SDB-1: Sürdürülebilirliğin boyutlarını belirleyebilmek	**Sürdürülebilirliğin Boyutları** **a.Sürdürülebilirliği bütün boyutlarıyla tanımlamak** (örn. çevresel-geri dönüşüm, sosyal(insanların mutluluğu, economik-kalkınma)	PST-1 PST-2 PST-3	PST-3: Ben sürdürülebilirliği hem insanların hem de çevrenin uyum içinde olması olarak tanımlıyorum. Kalkınırken çevrenin de korunması…	Yeterli
	b.Sürdürülebilirliği iki boyutlu tanımlamak (örn., çevresel- geri dönüşüm, atıkların azaltılması gibi)	PST-4,PST-5 PST-6,PST-7 PST-8	PST-7: Sürdürülebilirlik benim için geri dönüşüm demek. Döngüsel sisteme katkıda bulunmamız gerekiyor çünkü doğada herşey birbirine bağlı. Bütün canlı ve cansız varlıklar sürdürülebilirliğin bir parçası fakat, bazen biz bu döngüsel sisteme zarar veriyoruz.	Gelişmekte Olan

Bölüm II'nin sonunda katılımcılar Eymir Gölü'nün sürdürülebilir kullanımı üzerine bileşenleri ve bağlantıları düşünerek bir kavram haritası çizdiler. Kavram haritaları bileşenlerin ve bileşenler arasındaki ilişkilerin sayısı, karmaşıklık düzeyi (döngüsel ilişkiler mi yoksa daha çok hiyerarşik ilişkiler mi) ve gizli bileşenlerin varlığına göre kavram haritaların değerlendirilmesi için hazırlanan değerlendirme tablosu kapsamında değerlendirilmişlerdir. Değerlendirme tablosuna göre üç katılımcının sistemsel düşünme becerisi yeterli düzeyde ve beş katılımcının sistemsel düşünme becerisi gelişmekte olan düzeyine belirlenmiştir. Beş katılımcı Eymir'le ilgili kavramlar arasındaki ilişkileri, gizli bileşenleri göstermişlerdir ancak karmaşık, döngüsel ilişkilere daha az yer vermişlerdir. Yeterli düzeyde bulundan katılımcılar Eymir'i daha bütüncül bir sistem olarak değerlendirip kavramlar arasında daha karmaşık ilişkiler çizmişlerdir. Doğal sistemlerde her şeyin birbiriyle ilişkili olduğunu ve insanın da bunu parçası olduğunu göstermeye çalışmışlardır.

Özetle Eymir'e yapılan geziler fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin geliştirilmesine katkıda bulunmuştur. Veri analizi sonuçlarına göre sistemsel düşünme becerilerinden özellikle SDB-7'den SDB-12'ye kadar olan becerilerin gelişimi daha yavaştır. Buna göre bu becerilerin diğer becerilere göre daha karmaşık olduğu sonucuna varılmaktadır.

3.3.1.2.2 Sistemsel Düşünme Becerilerinin Geliştirilmesi- Bölüm III

Bölüm-III dört haftalık dersten oluşmaktadır. Bölüm III'de sürdürülebilir çözümler üzerine odaklanılarak kompost yapımı ve bahçe yapımı üzerine çalışılmıştır. Dönem boyunca fen bilgisi öğretmen adayları kompostun ve bahçenin bakımından sorumlu olmuşlardır. Katılımcılar bir gezi raporu hazırlamışlardır. Ders sonunda durum analizi, gezi raporu, görüşmeler ve kavram haritaları aracılığıyla veriler toplanmıştır. Ayrıca dersin son haftasında fen bilgisi öğretmen adaylarının final projesi olarak açık alanda SiE kapsamında bir ders planı hazırlamışlardır. Dönem sonunda yapılan veri analizi sonuçlarına göre sekiz katılımcının da sistemsel düşünme becerileri yeterli ve gelişmekte olan düzeylerinde bulunmuştur. Özellikle tüm katılımcılar Tablo-1'de sunulan becerilerden sürdürülebilirliğin boyutlarını belirleyebilmek (SDB-1), doğayı bir sistem olarak görebilmek (SDB-2), bir sistemin bileşenlerini belirleyebilmek (SDB-3), sürdürülebilirliğin boyutları arasındaki ilişkileri analiz edebilmek (SDB-4), gizli bileşenleri fark edebilmek

(SDB-5), sistemde kendi sorumluğunun farkına varabilmek (SDB-6), sistemin döngüsel doğasını fark edebilmek (SDB-8) ve diğer kişilerle empati kurabilmek (SDB-9) becerileri değerlendirme tablosuna göre en yüksek düzeyde yani yeterli düzeyde bulunmuştur. Diğer becerilerde ise (geçmiş, gelecek ve günümüz arasındaki ilişkiyi fark edebilmek (SDB-7), diğer canlılarla empati kurabilmek (SDB-10), mekan algısı geliştirebilmek (SDB-11) ve sistemsel düşünme perspektifini kendi yaşamına adapte edebilmek (SDB-12) daha yavaş bir gelişme göstermişlerdir. Bu becerilerin çoğu değerlendirme tablosuna göre yeterli ve gelişmekte olan düzeylerinde bulunmuştur. Sadece üç katılımcının SDB-12 becerisi yeni ortaya çıkan düzeyinde kalmıştır. Katılımcıların çoğu sürdürülebilirlik için daha basit davranışlarda bulunduklarından bahsetmişlerdir. Örneğin, geri dönüşüm yapmak, atıkları azaltmak gibi. Katılımcıların hiç biri sürdürülebilirlik için dönüştürücü davranışlarda bulunduklarından ya da bulunmayı planladıklarından söz etmemişlerdir. Buradan çıkarılan sonuca göre son beceri (SDB-12) bir ders kapsamında daha yavaş gelişmektedir. Kavram haritaları da katılımcıların sistemsel düşünme becerilerini geliştirdiğini göstermektedir. Ders sonunda katılımcıların çoğu karmaşık yapıda haritalar çizmişlerdir. Ayrıca son gezi raporundan çıkarılan sonuca göre kompost ve bahçe çalışması katılımcıların özellikle "sistemde kendi sorumluğunun farkına varabilmek" ve "sistemin döngüsel doğasını fark edebilme" becerilerinin gelişmesine katkıda bulunmuştur. Tablo 3'de sunulduğu gibi tüm katılımcıların becerileri dersin sonunda değerlendirme tablosundan çıkan sonuca göre yeterli düzeyde bulunmuştur.

Tablo 3.

Fen Bilgisi Öğretmen adaylarının görüşme sorularına göre sistemsel düşünme becerileri-Bölüm-III (temalar, kategoriler ve örnek maddeler)

	Tema ve Kategoriler	**Katılımcılar**	**Örnek Maddeler**	**Değerlendirme Düzeyi**
SDB-6: Sistemde kendi sorumluğunun farkına varabilmek	**Kendi sorumluluğunun farkına varmak** **a.Kendi sorumluluğunu ifade etmek**	PST-1 PST-2 PST-3 PST-4 PST-5 PST-6 PST-7 PST-8	PST-5: Bu ders sırasında kendi davranışlarımı daha çok düşünmeye başladım. Hepimiz bu sistemin bir parçasıyız. Bu sistemde kendi rolumun ve kendi sorumluluklarımın daha çok farkına varıyorum.	Yeterli
SDB-8: Sistemin döngüsel doğasını farkedebilmek	**Sistemin döngüsel yapısı** **a.Sistemin döngüsel yapısını açıklamak**	PST-1 PST-2 PST-3 PST-4 PST-5 PST-6 PST-7 PST-8	PST-1: Domates ve diğer bitkileri yetiştirmeyi öğrendik. Ancak bu sadece domates yetiştirmeyi öğrenmekle ilgili değil. Burda bütün herşeyin bir döngünün parçası olduğunu farketim. Bu ders sayesinde büyük resmi görmeye başladım.	Yeterli

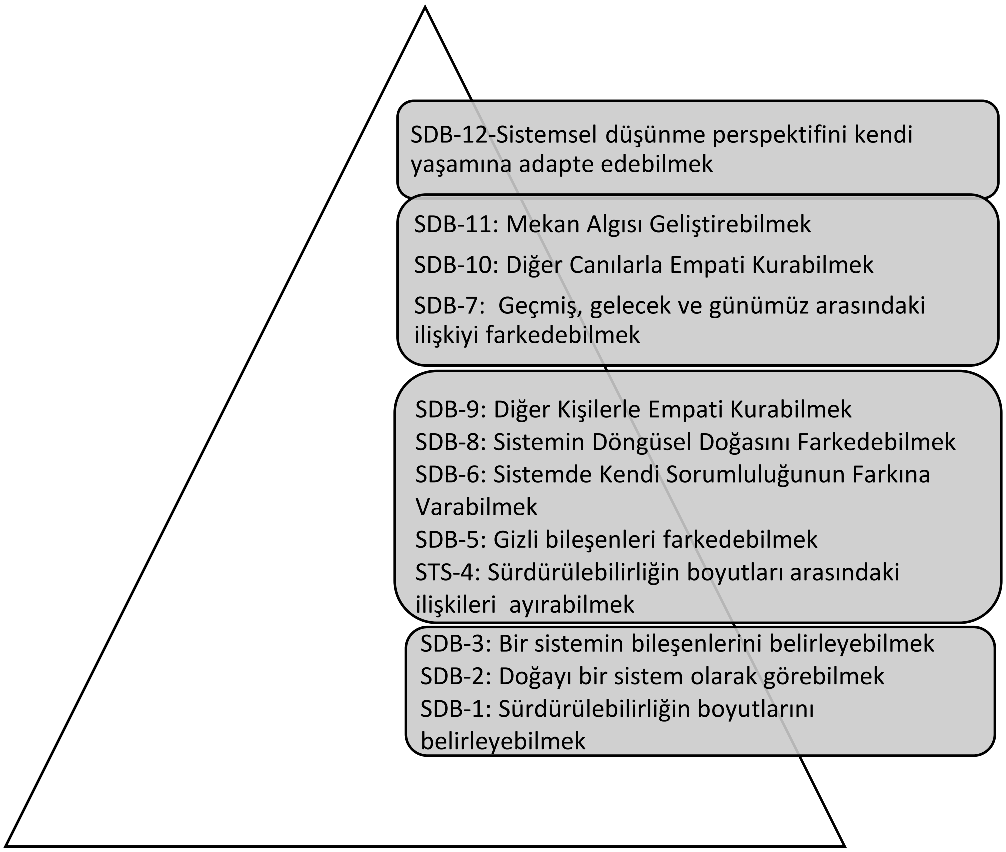
3.3.2 Araştırma Sorusu-6: Fen Bilgisi Öğretmen Adayları Sistemsel Düşünme Becerilerini Açık Alanda Sürdürülebilirlik için Eğitim Dersi Kapsamında Ders Planlarına Ne Ölçüde Yansıtabilirler?

Dönem sonunda fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini bir ders planına ne kadar yansıtabildiklerini belirleyebilmek için kendi seçtikleri bir konu üzerinde açık alan SiE kapsamında bir ders planı hazırlamaları istenmiştir. Hazırladıkları ders planlarına sistemsel düşünme becerilerini ne kadar bütünleştirebildikleri yine bir değerlendirme tablosune göre değerlendirilmiştir. Değerlendirme tablosunda kazanımlar, öğretim metodları ve değerlendirme bölümü olmak üzere üç bölümden oluşmaktadır. Ders planları özellikle beş konu üzerine hazırlanmıştır. Bunlar, ekosistem, toprak erozyonu, elektrik, geri dönüşüm ve vücudumuzdaki sistemlerdir. Ders planı analizi sonuçlarına göre katılımcılar ders sonunda geliştirdikleri sistemsel düşünme becerilerini ders planlarına yansıtabilmişlerdir. Örneğin, sürdürülebilirliğin boyutları, bir sistemin bileşenleri ve arasındaki ilişkiler, insanın sistemdeki rolü ve sistemin döngüsel doğası gibi becerileri ders planlarına entegre edebilmişlerdir.

Sonuç olarak, açık alanda SiE dersi fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerini geliştirmelerine katkıda bulunmuştur. Ancak bu gelişim iki sonuca bağlıdır. Bunlar bireysel farklılıklar ve becerilerin karmaşık yapısı. Bu sebeble analiz sonuçlarına göre iki grup ortaya çıkmaktadır. Bunlardan biri sistemsel düşünme becerilerinde yavaş gelişim gösterenler diğeri ise sistemsel düşünme becerilerinde önemli bir ilerleme gösterenlerdir. Birinci grupta yer alan üç katılımcının (PST-1, PST-2 ve PST-3) bazı mevcut sistemsel düşünme becerileri gelişmekte olan veya yeni ortaya çıkan düzeyindedir ve ders süresince daha yavaş bir gelişme göstermişlerdir. Ancak diğer beş katılımcının (PST-4, PST-5, PST-6, PST-7, PST-8) dersten önce mevcut sistemsel düşünme becerileri genellikle farkındalık öncesi iken ders süresince bu becerilerin en yüksek düzeye çıkarmışlardır (yeterli). Örneğin, PST-4 dersin başında Bölüm-I'de elde edilen verilerde sürdürülebilirliği sadece geri dönüşüm olarak tanımlamıştır. Ancak dersin sonunda sürdürülebilirliği kapsamlı bir şekilde, bütün boyutlarıyla tanımlayabilmiştir. Aşağıda katılımcının açıklaması verilmektedir:

> PST-4: Sürdürülebilirlik doğal kaynakları gelecek nesillerin de ihtiyaçlarını düşünerek kullanmaktır. Örneğin, Eymir gölünden her türlü faydalanabiliriz ancak gölü kullanırken doğasını da korumalıyız.

PST-4 aynı zamanda kavram haritasında kavramlar arasındaki karmaşık ilişkileri gösterebilmiştir. Yine sürdürülebilirliği merkeze alarak döngüsel system, sürdürülebilir tarım gibi pek çok bileşenlerle olan ilişkisini göstermiştir. Daha önce mevcut sistemsel düşünme becerileri düşük düzeyde olan katılımcılar ders süresince farkedilebilir düzeyde bir gelişme göstermişlerdir. Bireysel farklılıkların yanısıra becerilerin gelişimi karmaşıklığına göre de farklılık göstermektedir. Veri analizi sonuçlarına göre 12 sistemsel düşünme becerisi arasında dört hiyerarşik düzey olabileceği belirlenmiştir. Bunlardan SDB-1, SDB-2 ve SDB-3 en basit ve kolay gelişen beceriler olarak belirlenmiştir. İkinci sırada ise SDB-4, SDB-5, SDB-6, SDB-7, SDB-8 ve SDB-9 gelmektedir. Üçüncü sırada SDB-7, SDB-10 ve SDB-11 gelirken en üst sırada SBD-12 yer almıştır. Katılımcılardan bazıları SDB-12 (sistemsel düşünme perspektifini kendi yaşamına uyarlayabilmek) için yeni ortaya çıkan düzeyinde kalmışlar ve bu beceriyi geliştirememişlerdir. Ancak Şekil-1'de beceriler arasındaki hiyerarşik yapı gösterilmektedir.



Şekil-1. Sistemsel Düşünme Becerileri Arasındaki İlişki

TARTIŞMA VE SONUÇ

Tartışma bölümü üç başlık altında sunulmaktadır. Bunlar, fen bilgisi öğretmenlerinin SiE eğitmeni olabilmeleri için sahip olması gereken yeterlilikler, sistemsel düşünme becerisinin ölçülmesi ve fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerilerinin belirlenmesi ve sistemsel düşünme becerilerinin açık alanda SiE dersi ile geliştirilmesidir.

5.1 Fen Bilgisi Öğretmenlerinin SiE Eğitmeni Olabilmeleri için Sahip Olması Gereken Yeterlilikler

Fark analizi sonuçlarına göre fen bilgisi öğretmenlerinin sahip olması gereken yeterlilikler SiE eğitmenlerinin yeterliliklerini kapsamamaktadır. Bunun bir sebebi eğitim programlarında sürdürülebilirliğin ve SiE eğitimin yer almamasıdır. Örneğin, Türkiye'deki üniversitelerin eğitim fakültelerinde öğretim üyeleriyle yapılan bir araştırmada öğretim üyelerinin sürdürülebilirliği derslerine entegre etmedikleri tespit edilmiştir (Cavas ve digerleri, 2014). Benzer şekilde öğretmen adayları ve öğretmenler de SiE kavramına yeteri kadar aşina değillerdir. Örneğin, Cebriyan ve Junyet (2015) İspanya'da uyguladıkları bir çalışmada öğretmen adaylarının SiE yeterliliklerine sahip olmadıkları sonucuna ulaşmışladır. Benzer şekilde Burmeister ve arkadaşları (2013) fen bilgisi öğretmenlerinin SiE ile ilgili yeteri kadar bilgi ve beceriyle sahip olmadıklarını belirlemişlerdir. Bu çalışmada fark analizi sonucuna göre sistemsel düşünme becerilerinin fen bilgisi öğretmenlerinin SiE eğitmeni olabilmeleri için sahip olması gereken yeterliliklerden biri olduğu tespit edilmiştir. SiE alan yazınında da sistemsel düşünme özellikle yüksek öğretimde geliştirilmesi gereken önemli bir yeterlilik olduğu araştırmacılar tarafından ifade edilmiştir (Wiek ve arkadaşları, 2011; Rieckmann ve arkadaşları, 2012). Fen bilgisi eğitimi alan yazınında da araştırmacılar sistemsel düşünmeyi 21.yüzyıl becerilerinden olduğunu ve öğrencilerin sistemsel düşünme becerilerinin geliştirilmesi gerektiğini ifade etmişlerdir (Assaraf ve Orion, 2005; 2010; Chandi, 2008; Hogan ve Weathers).

5.2 Sistemsel Düşünme Becerilerinin Ölçülmesi ve Fen Bilgisi Öğretmen Adaylarının Mevcut Sistemsel Düşünme Becerilerinin Belirlenmesi

Bu çalışmada fen eğitimi ve SiE alanında 12 sistemsel düşünme becerisi belirlenmiştir. Bu becerileri duyusal, bilişsel ve psikomotor alanları kapsamaktadır. Alan yazınında bazı çalışmalarda da sistemsel düşünme farklı alanları içerecek şekilde ifade edilmiştir (örn., Sleurs, 2008; UNECE, 2011). Aynı zamanda sistemsel düşünme becerilerini ölçmek için bir dizi ölçme araçları hazırlanmıştır (örn., deneme yazımı, durum analizi, görüşmeler, kavram haritaları ve gezi raporları). Alan yazınında fen eğitimi, SiE ve farklı alanlarda nitel ölçme araçları kullanılmıştır (örn., Assaraf ve Orion, 2010; Brandstadter ve diğerleri, 2012; Connel ve diğerleri, 2012). Deneme yazımı, durum analizi ve kavram haritaları spesifik sistemsel düşünme becerilerini ölçmek için özellikle fazla sayıdaki örneklemlerde etkili bir şekilde kullanılabilir (Brandstadter ve diğerleri, 2012). Görüşmeler sistemsel düşünme becerilerini ölçmek için kullanılan etkili yöntemlerden biridir (Assaraf & Orion, 2010a, 2010b). Bu çalışmada da olduğu gibi görüşmeler sistemsel düşünme becerileri ile ilgili daha kapsamlı bilgi verir.

Ana çalışma başlamadan önce fen bilgisi öğretmen adaylarının mevcut sistemsel düşünme becerileri ölçülerek genellikle yeni ortaya çıkan ya da farkındalık öncesi düzeylerinde bulunmuştur. Dutton-Lee (2015) tarafından yapılan bir çalışmada da fen bilgisi öğretmen adaylarının ve fen bilgisi öğretmenlerinin sistemsel düşünme becerileri ölçülmüş ve bazı becerilerinin (örn., bir sistemdeki bileşenleri ve etkileşimleri belirleyebilme) düşük düzeyde olduğu tespit edilmiştir. Barak ve Dori (2009) yaptıkları bir çalışmada fen bilgisi öğretmenlerinin sistemsel düşünme becerilerinin üniversitede öğretmen eğitimi programlarına entegre edilerek geliştirilmesi gerektiğini ifade etmişlerdir.

5.3 Sistemsel Düşünme Becerilerinin Açık Alanda SiE ile Geliştirilmesi

Açık alanda SiE dersi fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin gelişmesinde önemli rol oynamıştır. Özellikle Eymir Gölü'ne yapılan gezilerde katılımcılar Eymir'i farklı açılardan inceleyerek sürdürülebilirliğin farklı boyutlarını keşfetmişlerdir. Alan gezileri aynı zamanda doğal sistemleri anlayarak insanın bu sistemin bir parçası olduğunu farketmelerine olanak sağlamıştır. Beames ve diğerleri (2012) açık alanda eğitimin komplex sistemleri anlaşılmasında ve insan-doğa ilişkisinin farkedilmesine önemli rol oynadığını ifade etmişlerdir. Örneğin, kompost yapımı ve bahçe etkinlikeri de katılımcıların sistemde kendi rollerini, sorumluluklarını farketmelerine ve doğal sistemlerin döngüsel yapısını anlamalarına yardımcı olmuştur. Aynı zamanda Assaraf ve Orion (2010b) yaptıkları bir çalışmada açık alanda eğitimin kişilerin döngüsel sistemi anlamalarına ve sistemde kendi rollerinin farkına varmalarına yardımcı olduğunu bulmuşlardır. Capra (1999) bahçe çalışmasının sistemsel düşünmeyi harekete geçiren önemli bir etkinlik olduğunu ifade etmiştir.

Bu çalışmadan elde edilen diğer bir sonuç ise 12 sistemsel düşünme becerileri arasında karmaşık ve hiyerarşik bir ilişki olduğudur. Örneğin, "Sistemsel düşünme perspektifini kendi yaşamına uyarlayabilmek" (SDB-12) becerisi en kompleks beceri olarak değerlendirilmiştir (Şekil-1). Bu çalışmanın sonunda katılımcıların çoğunluğu bu beceri için gelişmekte olan ya da yeni ortaya çıkan seviyesinde kalmışlardır. SDB-12 dersin sonunda yeterli düzeyde bulunamamıştır. Bu nedenle bazı beceriler daha karmaşık oldukları için gelişmesi zaman almaktadır. Assaraf ve Orion (2005) kendi çalışmalarında sistemsel düşünme becerileri arasında hiyerarşik bir ilişki olduğunu keşfetmiştir. Aynı zamanda katılımcıların sistemsel düşünme becerileri onların daha önceki bilgi ve tecrübelerine dayalı olarak değişiklikler göstermektedir. Katılımcıların becerileri onların inanç, değer ve davranışlarına göre değişiklik gösterebilir ve bu farklılıklar düşünme yapılarını etkiler (Sterling ve arkadaşları, 2005). Özet olarak bu çalışmadan elde edilen sonuçlar şu şekilde sunulabilir:

1. Fark analizi sonucunda sistemsel düşünmenin fen bilgisi öğretmen adaylarınının SiE eğimeni olabilmeleri için gerekli olduğu bulgusuna ulaşılmıştır.
2. İlgili alan yazınına göre fen eğitimi ve SiE alanında 12 sistemsel düşünme becerisi belirlenmiştir.
3. Sistemsel düşünme becerilerini geliştirmek için beş farklı nitel ölçme araçları geliştirilmiştir.
4. Pilot çalışma ile ölçme araçlarının geçerlilik ve güvenirlikleri test edilerek 12 sistemsel düşünme becerisinin bu beş ölçme aracıyla ölçülebileceğine karar verilmiştir.
5. Pilot çalışma sonucunda fen bilgisi öğretmen adaylarının sistemsel düşünme becerilerinin tahmin edildiği gibi yeterli düzeyde olmadığı belirlenmiştir.
6. Son olarak sistemsel düşünme becerilerinin açık alanda SiE ile geliştirilebileceği ancak bireysel farklıkların ve becerilerin karmaşık yapısının da göz önünde bulundurulması gerektiği sonucuna varılmıştır.

ÖNERİLER

Bu çalışmanın sonuçları fen bilgisi öğretmen adaylarını ve fen bilgisi öğretmenlerini SiE alanında eğitmek için sistemsel düşünme becerilerinin geliştirilmesi gerektiğini ortaya koyarak bu alanda çalışan araştırmacılara ve eğitimcilere yeni bir pencere açmaktadır. 12 sistemsel düşünme becerileri hem fen eğitimi hem de SiE alanında daha detaylı olarak çalışılabilir. Tezde geliştirilen nitel ölçme araçları farklı alanlara adapte edilerek tekrar kullanılabilir. Böylelikle ölçeklerin güvenirlik ve geçerliliği pekiştirilmiş olur. Bu ölçme araçlarından deneme yazımı, durum analizi ve kavram haritaları özellikle geniş örneklemlerde daha hızlı sonuç almak için kullanılabilir. Ancak tezden elde edilen sonuçlara göre görüşmeler 12 sistemsel becerisini ölçmede daha etkilidir. Yukarıda bahsedilen ölçme araçları görüşmelerle desteklenirse sistemsel düşünme becerileri ile ilgili daha detaylı sonuçlar elde edilebilir. Açık alanda SiE dersi sürdürülebilirlikle ilgili yeni konular eklenerek geliştirilebilir. Aynı zamanda gelecek çalışmalarda araştırmacılar sistemsel düşünme becerilerinin gelişiminde önemli rol oynayan kişisel özellikler de göz önüne alarak durum analizi çalışması yapabilirler. Bu şekilde her bir katılımcıyı bir durum olarak ele alıp onların sistemsel düşünme gelişimini izleyebilirler. Sonuç olarak fen eğitimi ve SiE alanında sistemsel düşünme becerileri yeni bir araştırma alanıdır. Bu nedenle bu çalışmanın farklı konular üzerinde, farklı eğitim seviyelerinde (okul öncesi, ilköğretim gibi), farklı öğretmen eğitimi alanlarında ve farklı kültürlerde tekrar edilmesi önerilmektedir. Günümüzde sistemsel, çok boyutlu sorunların üstesinden gelebilmek ve sürdürülebilir çözümler üretebilmek için her bireyin sistemsel düşünme becerilerine sahip olması önemli bir gerekliliktir.

APPENDIX J: CURRICULUM VITAE

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High School	Isparta Anadolu High School	2002

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Year	Place	Enrollment
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FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

JOURNAL ARTICLES

Karaarslan, G., & Sungur, S. (2011). Elementary students’ self-efficacy beliefs in science: Role of grade level, gender, and socio-economic status. *Science Education International, 22* (1), 72-79.

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Çakır, B., **Karaarslan**, G., Yılmaz-Tüzün, Ö., Ertepınar, H., & Alp-Şahin E. (2009). Relationships among pre-service science teachers' environmental attitudes, beliefs and nature relatedness, paper presented at the *the European Science Education Research Association (ESERA),2009, İstanbul, Turkey, August 31-September 4.*

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Karaarslan, G. (2010). The Effect of Gender, Grade Level and Background Characteristics on Elementary School Students' Science Self Efficacy Beliefs, paper presented at the European Conference on Educational Research (ECER) in Helsinki, FINLAND, August 23-24.

Karaarslan, G., Ertepinar, H.., & Sungur, S. (2010). A survey on Turkish preservices science teachers' motivation toward environment, *paper presented at the International organization for science and technology education (IOSTE) 2010, Bled, SLOVENIA, June 13-18.*

Karaarslan, G., Ertepinar, H.., & Sungur, S. (2011). Satisfaction of pre-service science teachers basic psychological needs while solving an environmental problem, *paper presented at the National Association for Research in Science Teaching (NARST) 2011*, Orlando, FL, USA April 3-6.

Karaarslan, G., Ertepınar, H., & Sungur, S. (2011). Fostering pro-environmental behaviors through examination of an environmental problem, *Paper presented at the European Science Education Research Association (ESERA), 2011,* Lyon, France, September 5-9.

Cakir, B., **Karaarslan**, G., Ertepınar, H., & Sahin, E. (2011). Predicting university students' environmental behavior via nature relatedness, environmental concern and environmentally desirable response variables, *paper presented at the European Conference on Educational Research (ECER) 2011,* Berlin, Germany, September 12-13.

Karaarslan, G., Cakir, B., Sahin, E., Ertepinar, H., & Oktay, O. (2012). Which one predict University students'pro-environmental behavior more? Nature relatedness or environmental motive concern?, *paper presented at the National Association for Research in Science Teaching (NARST) 2012,* Indiana, USA, March 25-28.

Karaarslan, G., & Teksöz, G. (2012). Pre-service teachers' understandings of sustainable development, *paper presented at the international symposium on science centers and sustainable development (SSCS, 2012),* İstanbul, TURKEY, June 11-13.

Karaarslan, G., & Teksöz, G. (2013). Pre-service science teachers' experiences on outdoor environmental education through 3 field trips, *paper presented at the 7th world environmental education congress (WEEC, 2013),* Marrakech, MOROCCO, June, 9-14.

Karaarslan, G., Çakır, B., Şahin, E., & Ertepınar, H. (2013). University students' understandings of sustainability and their environmentally friendly behaviors in Turkey, *paper presented at the 7th world environmental education congress (WEEC, 2013),* Marrakech, MOROCCO, June, 9-14.

Karaarslan, G., & Mehmetlioğlu, D. (2013). Sustainability practices in the university campuses: Three UK models of sustainable campuses, *paper presented at the European Conference on Educational Research (ECER)* in İstanbul, Turkey, September 9-13.

Karaarslan,G., & Teksöz, G. (2014). Science Teachers as ESD Educators: Gap Analysis *paper presented at the 1st Eurasian Educational Research Congress (EJER),* İstanbul, Turkey, Nisan 24-26.

Karaarslan, G., & Teksöz, G. (2015). Developing Systems Thinking Skills of Pre-Service Science Teachers for becoming ESD Educators: An attempt from Turkey, *paper presented at the World Environmental Education Congress (WEEC),* Gothenburg-Sweden, June 29, July 2 2015.

Karaarslan, G., & Teksöz, G. (2015). Landscape shapes mindscape: An experience on place based outdoor education, *paper presented at North American Association for Environmental Education (NAAEE)*, San diego-USA, October 15-18 2015.

Karaarslan, G., & Teksöz, G. (2015). *What Does a Tree Mean to You? Do Turkish Pre-service Science Teachers Hold Initial Systems Thinking Skills?* Paper presented at European Educational Research Association (ECER), Budapest-Hungary, 07-11 September, 2015.

Karaarslan, G., & Mehmetlioglu, D. (2015). Transforming mathematics Education for Sustainabilitiy: An Initial attempt. Paper presented at International Congress on Education for the Future: Issues and Challenges, Ankara-Turkey, 13-15 May 2015.

Mehmetlioglu, D., & **Karaarslan,** G. (2015). Looking into mathematics education in early childhood through sustainability lens. Paper presented at 2015 OMEP World Assembly and Congress, Washington, America, July 27- August 1.

NATIONAL CONFERENCE PAPERS

Karaarslan, G., Çakır, B., Ertepınar, H. & Şahin, E. (2010). Eğitim Fakültesi Öğrencilerinin Doğaya Bağlılıkları ve Çevre Dostu Davranışları, *paper presented at the 9. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi (UFBMEK) 2010, İzmir, TURKEY, September 23-24.*

Karaarslan, G., Çakır, B., Şahin, E., & Ertepınar, H.(2011). Relationship among university students' pro-environmental behavior, nature relatedness and environmental concern, *paper presented at the International Conference on New Trends in Education and Their Implications (ICONTE), 2011,* Antalya, TURKEY, April 27-29.

COURSES/SUMMER SCHOOLS

The Darwin Scholarship Programme- Monitoring and Communicating Biodiversity Course, Shrewsbury & Dorking, Nr London, UK (21-31 August 2012)

Values and Competency based Outdoor Education for Sustainability, Betwsy-Coed, UK (13-18 April 2014)

Visiting three Sustainable Universities in UK (Oxford Brookes University, Univesity of East Anglia and University of Salford (19-21 July, 2011)

The Future of Outdoor Learning in a Changing World, Castle Head Field Centre, UK, 6-8 November 2014

AWARDS/CERTIFICATES

Turkish Science and Technology Research Institution, Master of Education Scholarship, 2007-2009

British Council-Middle East Technical University- "Towards a Sustainable METU Campus Student Project Competition", premier award- May 2011

The Darwin Scholarship Programme- Monitoring and Communicating Biodiversity Course, Shrewsbury & Dorking, Nr London, UK (21-31 August 2012)

HOBBIES

Birdwatching, permaculture, eco-villages, yoga, cycling

APPENDIX K: TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü

Sosyal Bilimler Enstitüsü

Uygulamalı Matematik Enstitüsü

Enformatik Enstitüsü

Deniz Bilimleri Enstitüsü

YAZARIN

Soyadı : KARAARSLAN

Adı : Güliz

Bölümü : İlköğretim

TEZİN ADI (İngilizce) : Science Teachers as ESD Educators: An Outdoor ESD Model for Developing Systems Thinking Skills

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. Tezimden bir (1) yıl süreyle fotokopi alınamaz.

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: