SCIENCE LITERACY IN REGARD TO THE ENVIRONMENT:

ISSUES AND CHALLENGES

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ABSTRACT

This dissertation analyzes different aspects of environmental literacy. It contains two interrelated research fields. The first research field comprises four studies and focuses on the environmental literacy of 15-years-old students in different counties based on PISA data. The second research field comprises two Delphi studies with experts of environmental education. These studies focus on the concepts, contexts and competences of environmental literate individuals, as well as teacher education aspects.

The purpose of research is that in future raw material resources will be consumed faster than today. So, nowadays individuals who are sensitive to the environment are increasingly needed. Therefore, the concept of environmental literacy should be integrated in science education. Moreover, science curricula, textbooks, and teacher education should be revised to integrate the environmental literacy and to develop common universal value for nature, individuals and society. Due to these reasons, there is a need for comprehensive and detailed research on environmental literacy.

In this dissertation, one of the aims is to determine the factors that influence the environmental literacy and to compare the environmental literacy of pupils in Germany, Singapore and Estonia. The second purpose is to identify the consensus of experts on environmental literacy to revise the definition and framework of environmental literacy. Finally, it aims to integrate the concept of the environment into teacher education and STEM education. STEM stands for Science, Technology, Engineering, Mathematics, and is a new science education (SE) reform approach in different countries.

The first research field includes four studies based on PISA data. In the first research field, it is determined both ‘the factors that affect the environmental literacy of 15-year old students in Germany’, and ‘the change in the environmental literacy of German students from 2006 to 2015’, respectively (**Study-1** and **Study-2**). The purpose of **Study-3** is to ‘compare the variance of the main factors affecting the environmental literacy of fifteen-years-old students studying in Singapore, Estonia and Germany’. The aim of the **study-4** is to determine both ‘the dimensions including “effects of family, teacher, student, and teaching” that influence the environmental literacy’, and ‘the effects of environmental perceptions including "environmental awareness, environmental responsibility and environmental optimism" on science literacy (SL)' through using PISA data.

In the second research field, it is aimed to reach the consensus of experts on the framework of environmental literacy (**study-5**) and to determine 'what teachers should do to their experiences and qualifications as environmental STEM literate individuals' (**study-6**) based on responses within Delphi studies. Moreover, this research field demonstrates the necessity of integrating the concept of the environment into STEM education and into pedagogical content knowledge (PCK).

Pragmatic Paradigm is adopted as philosophy. As research design, sequential mixed methods are used. In this process of dissertation, the first four studies are designed as quantitative research. After the quantitative studies, the 5th- and 6th-studies are carried out with the Delphi method which includes both qualitative and quantitative studies respectively. This method is an exploratory sequential mixed method approach.

The inclusion of environmental literacy within the framework of international large-scale research might expand awareness of environmental literacy. Moreover, the integration of international large-scale research and qualitative research might contribute more to environmental literacy universally. In this way, revision and updating the environmental literacy within the educational system, which is continuously developing, might be realized more effectively. Finally, in further studies related environmental literacy, the factors that affect environmental literacy and framework of the environmental literature, which is obtained from expert's opinions should be also taken into consideration. In addition, the concept of the environment should be integrated into current education reforms especially STEM education and teacher education.

Keywords: Environmental Literacy, Science Literacy, Comparative Study, Delphi Study, Mixed Method, PISA, Pedagogical Content Knowledge, Science Education, STEM Education

ZUSAMMENFASSUNG

In diesem Promotionsprojekt werden unterschiedliche Aspekte einer umweltbezogenen Grundbildung (Environmental Literacy) analysiert. Die Arbeit umfasst zwei miteinander verknüpfte Forschungsfelder. Das erste Forschungsfeld umfasst vier Studien basierend auf PISA Daten mit Fokus auf Environmental Literacy von 15 Jahre alten Schülerinnen und Schülern aus unterschiedlichen Ländern. Das zweite Forschungsfeld umfasst zwei Delphi Studien durchgeführt mit Experten der Umweltbildung aus unterschiedlichen Ländern. Im Fokus dieser Delphi Studien stehen Konzepte, Kontexte und Kompetenzen bezogen auf die Environmental Literacy sowie Aspekte der Lehrerbildung.

Anlass der Dissertation ist die Annahme, dass in der Zukunft natürliche Ressourcen wie etwa Rohstoffe schneller verbraucht werden als heute. Deshalb ist es notwendig, dass die heutige Gesellschaft zunehmend für Umweltfragen sensibilisiert wird. Das macht es notwendig, das Konzept der Environmental Literacy in den Naturwissenschaftsunterricht zu integrieren. Naturwissenschaftliche Curricula, Schulbücher und die Lehrerbildung sollen dahingehend überarbeitet werden, dass gemeinsame universelle Werte bezogen auf Natur, Mensch und Gesellschaft als Aspekte der Environmental Literacy integriert werden. Aus diesen Gründen ist eine umfassende und detaillierte Forschung über Environmental Literacy erforderlich.

Die Ziele dieser Dissertation sind vielfältig und umfassen die Bestimmung der Faktoren, welche die Environmental Literacy maßgeblich beeinflussen, sowie einen Vergleich der Environmental Literacy von Schülerinnen und Schülern aus Deutschland, Singapur und Estland. Ein weiteres Ziel ist das Finden eines Konsenses unter Experten der Umweltbildung bezogen auf Fragen zu den Dimensionen und dem Rahmen von Environmental Literacy. Das letzte Ziel ist die Integration des Konzeptes der Umwelt in die Lehrerbildung und STEM Bildung. STEM steht für Science, Technology, Engineering, Mathematics und ist ein neuer naturwissenschaftlicher Reformansatz in unterschiedlichen Ländern.

Das erste Forschungsfeld umfasst Analysen basierend auf PISA Daten zu "Faktoren, welche die Environmental Literacy von 15 Jahre alten Schülerinnen und Schülern in Deutschland beeinflussen" sowie zur "Veränderung der Environmental Literacy von deutschen Schülerinnen und Schülern von 2006 bis 2015" (**Studie-1** und **Studie-2**). Das Ziel einer weiteren Studie (**Studie-3**) ist der "Vergleich der Varianz der Hauptfaktoren, welche die Environmental Literacy von 15 Jahre alten Schülerinnen und Schülern aus Singapur, Estland und Deutschland"

beeinflussen. Das Ziel der **Studie-4** ist die Bestimmung der "Dimensionen (Effekte der Familie, Lehrer, Schüler und Unterricht), welche die Environmental Literacy beeinflussen", sowie die Bestimmung der "Effekte auf umweltbezogene Einstellungen (Umweltwahrnehmung, Umweltverantwortung, Umweltoptimismus) auf die naturwissenschaftliche Grundbildung (Science Literacy)".

Die Ziele im zweiten Forschungsfeld umfassen die Konsensfindung unter Experten der Umweltbildung bezogen auf die Dimensionen und den Rahmen einer Environmental Literacy (**Studie-5**) sowie die Festlegung "was Lehrkräfte machen sollen, um ihre Erfahrungen und Qualifikationen als "Environmental STEM Literate Individuen" zu erweitern" (**Studie-6**). Die Studien basieren auf Delphi Befragungen. Ergänzend dazu wird die Notwendigkeit der Integration eines Umweltkonzepts in die STEM Bildung und in das Pädagogische Inhaltswissen (PCK) von Lehrkräften aufgezeigt.

Das Pragmatische Paradigma als Philosophie ist der grundlegende Forschungsansatz. Sequentiale Mixed-Method – einer der anerkannten Mixed-Method Ansätze – wird dabei als Forschungsdesign verwendet. In den ersten vier Studien kommen quantitative Forschungsmethoden zum Einsatz. An die quantitativen Analysen anschließend werden in Studie-5 und Studie-6 Delphi Methoden angewendet. Diese umfassen sowohl qualitative als auch quantitative Analysen und stehen im Forschungsparadigma eines explorativen, sequentialen Mixed-Method Ansatzes.

Durch die Verbindung von Environmental Literacy mit dem internationalen Large-Scale Forschung (PISA) wird die Wahrnehmung dieses Konzeptes universell erweitern. Darüber hinaus soll die Vernetzung von internationaler Large-Scale Forschung und qualitativer Forschung zum Verständnis von Environmental Literacy beitragen. Revision und Aktualisierung des Ansatzes der Environmental Literacy in sich kontinuierlich weiter entwickelnden Bildungssysteme können dadurch effektiver umgesetzt werden. In weiterführenden Studien, die sich auf Environmental Literacy beziehen, sollen die Faktoren, welche die Environmental Literacy beeinflussen und der theoretische Rahmen, der von den Expertenbefragungen abgeleitet wurde, beachtet werden. Ergänzend dazu soll das Umweltkonzept in modern Bildungsreformen - vor allem in die STEM Bildung und in die Lehrerbildung – integriert werden.

Schlüsselbegriffe: Environmental Literacy, Science Literacy, Vergleichsstudie, Delphi Studie Mixed Method, PISA, Pädagogisches Inhaltswissen, Naturwissenschaftliche Bildung, STEM Bildung.

LIST OF RESEARCH FIELDS AND STUDIES IN THESIS

I. **Research Field-I:** Large-Scale Assessment

Study (1) Kaya, V. H. and Elster, D. (2018). German Students' Environmental Literacy in Science Education Based on PISA Data, *Journal of Science Education International*, *29* (2), 75-87.

Study (2) Kaya, V. H. and Elster, D. (2017). Change in the Environmental Literacy of German Students in Science Education between 2006 and 2015, *The Turkish Online Journal of Educational Technology, Special Issue for INTE 2017*, 505-524.

Study (3) Kaya, V. H. and Elster, D. (2018). Comparison of the Main Determinants Affecting Environmental Literacy Between Singapore, Estonia and Germany, *International Journal of Environmental and Science Education, 13* (3), 1-17.

Study (4) Kaya, V. H. and Elster, D. (accepted). Dimensions Affecting Environmental Literacy, and Environmental Perceptions Influencing Science Literacy, *International e-Journal of Educational Studies,3*(6), 1-9.

II. **Research Field-II:** Delphi Studies

Study (5) Kaya, V. H. and Elster, D. (Submitted). A Critical Consideration of Environmental Literacy: Concepts, Contexts and Competencies, *Sustainability*.

Study (6) Kaya, V. H. and Elster, D. (2019). Environmental Science, Technology, Engineering, and Mathematics Pedagogical Content Knowledge: Teacher's Professional Development as Environmental Science, Technology, Engineering, and Mathematics Literate Individuals in the Light of Experts' Opinions, *Journal of Science Education International, 30* (1), 11-20.

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LIST OF ABBREVIATIONS

ATSch	: Attitude towards School
ATSci	: Attitude toward Science
ATTS	: Attitude of Teachers Towards the Student
CM	: Class Management
DEB	: Development of Environmental Behavior
ECA	: Extra-Curricular Activities
EE	: Environmental Education
EL	: Environmental Literacy
ELP	: Educational Level of Parents
EO	: Environmental Optimism
ESD	: Education for Sustainable Development
ESP	: Education Support of Parents
ISCK	: Interest in Science Content Knowledge
PCK	: Pedagogical Content Knowledge
PISA	: Programme for International Student Assessment
SE	: Science Education
SEC	: Socio-Economic Characteristics
SL	: Science Literacy

SPSS	: Statistical Package for the Social Sciences
STEM	: Science, Technology, Engineering and Mathematics
TAS	: Test Anxiety of Student
TC	: Teaching Characteristics
TDT	: Teacher's Disposition to Teaching
TFADS	: Teacher’s Feedback for Academic Development of Student
TPCK	: Technological Pedagogical Content Knowledge
TTS	: Teacher’s Teaching Skills
TW	: Teamwork
UNESCO	: United Nations Educational, Scientific and Cultural Organization
VIF	: The Variance Inflation Factor

SECTION 1. INTRODUCTIONAL PART

Introductional part includes ‘theoretical background and literature review’, ‘introduction and methods’, ‘results’, ‘discussions and conclusions’ and ‘implications and recommendations’.

Chapter 1. Theoretical Backround and Literature Review

In this section, theoretical background and literature review are included about Science Literacy (SL) in respect to the environment. The section comprises subsections about ‘nature and environment’, ‘the importance and role of the environment in science literacy: Issues’, ‘historical development of environmental literacy’, ‘the significance of pedagogical content knowledge in teacher education’, ‘STEM education’, and ‘science literacy in respect to the Environment: Challenges’.

1.1. Nature and Environment

Especially in biology education, nature is a fundamental term, because nature and its processes need to be understood and related to in many contexts, in relation to socio-scientific issues concerning the environment (Lindahl and Linder, 2015). Therefore, the framework of both nature and its conservation is constantly developing (Table 1).

Every passing day, understanding of ‘conservation of nature’ and ‘science underpinning’ is widened continuously. In 1960, the framing of conservation included nature for itself, and science underpinning was to species, habitats and wildlife ecology. Nowadays, however, the framework of conservation includes people and nature, and science underpinning is to interdisciplinary, social and ecological sciences (Mace, 2014).

Table 1.1: Changing views of nature and conservation (Mace, 2014)

Rough timeline	**Framing of conservation**	**Key ideas**	**Science underpinning**
1960-1980	Nature	Species, Wilderness, Protected areas	Species, habitats and wildlife ecology
1980-2000	Nature	Extinction, threats and threatened species, Habitat loss, Pollution, Overexploitation	Population biology, natural resource management
2000-2010	Nature	Ecosystems, Ecosystem approach, Ecosystem services, Economic values	Ecosystem functions, environmental economics
2010-…	People and Nature	Environmental change, Resilience, Adaptability, Socioecological systems	Interdisciplinary, social and ecological sciences

The term "nature" may include living plants and animals, geological processes, weather, and physics, such as matter and energy. Additionally, the nature often refers to wilderness - wild animals, rocks, forest, beaches, and in general areas that have not been substantially altered by humans, or which persist despite human intervention (Environment and Ecology, 2018b). In other words, the phenomena of the physical world collectively includes plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations (Oxford Dictionaries, 2018b).

On the other hand, the natural environment, commonly referred to as the “environment”, is a term that encompasses all living and non-living things occurring naturally on Earth (Environment and Ecology, 2018a). The surroundings or conditions in which a person, animal, or plant lives or operates (Oxford Dictionaries, 2018a). In other words, the concept of environment is to integrate the dimensions of nature and the biosphere such as forests, deserts, lakes and so on, and the dimensions of the anthropogenic environment such as buildings, aero planes and so on.

While the scope of both nature and environment is compared, the framework of the environment is more widen that ‘nature’ as, the term 'environment' includes not only nature but also dimensions of economic, social and politics (Figure 1). Moreover, the environment has an interlinked array of political, social, economic and biophysical environmental dimensions (O`Donoghue, 1989).

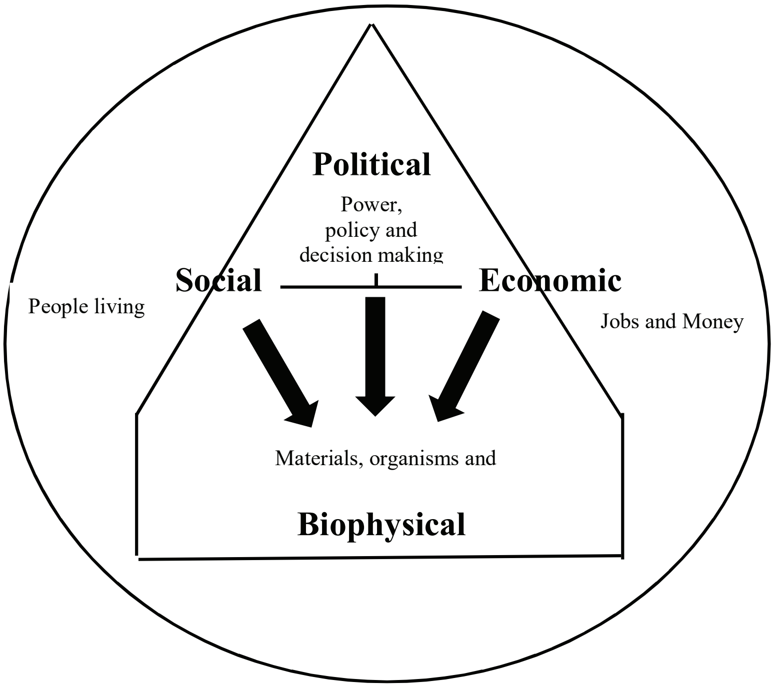


Figure 1.1: The terminology of nature and the environment by O`Donoghue (1989: 16).

As a result, in this study, the concept of 'environment' is preferred to determine the effects of people on nature and the factors that affect the perception and behavior towards nature.

1.2. The Importance and the Role of the Environment in Science Literacy: Issues

Science is very significant for individuals if they are to make sense of their lives (Godek, 2002). Therefore, scientific literacy has become a concept common to the basic goals of science education (SE) (Gabel, 1976). Moreover, scientific literacy has become the basis on which individuals can fully participate in society (Bybee, 2008). Through SE and the SL that results from it, individuals gain the ability to engage with science-related issues and scientific ideas (OECD, 2013). Scientific literacy is defined as the capability of using scientific information, asking questions and making conclusions based on proof for comprehending the natural world (OECD, 2006: 12; OECD 2009a: 128).

One of the important elements of SL should be considered as the environment and its protection. Therefore, individuals are able to convey and make use of the main ecological concepts and rules, make sense, on ecological grounds, of the effect of human activities on the environment, determine and carry research about environment-related matters to come up with different solutions, and assert the values related to the environment that encourage the use of natural resources in a sensible and responsible manner (Subbarini, 1998: 45).

Ultimately, more qualified individuals should be educated for the protection of the natural sources effectively. Therefore, a comprehensive study on EL is required to support the new educational reforms.

1.2.1. Environmental Literacy and Its Importance in Science Education

Human consumption, agriculture, and technology make life more comfortable and safer, but also harm the environment (Polat, Kaya, and Karamuftuoglu, 2014). Therefore, deficient individual understanding of the fundamental environmental problem is often cited as a cause of environmental deterioration (Schneider, 1997). The environmental problems affect not only human beings, but also all living beings. Therefore, we need more environmentally literate individuals for a life-world, and also, we expect them to adapt to the changes and dynamics of environmental resources and systems (Scholz, 2011). EL is the capacity to recognize and understand the actual ecological situation and to take appropriate action to maintain, restore and improve the health of environmental systems (Roth, 1992). EL as a part of the scientific literacy gives individuals the ability to engage with science-related issues and scientific ideas (OECD, 2013).

In 1990, the term of EL is clarified and redefined with the development of EE (Roth, 1992). However, researchers continue to present new definitions of this concept. One such definition is:

> *"A person competent in terms of the environment who spreads and implements primary ecological concepts and principles, knows how human activities affect the environment from an ecological perspective, possesses the skills needed to define and investigate environment-related issues and alternative solutions and adopts environmental values necessary for responsible use of environmental resources."* (Subbarini, 1998: 245)

As North American Association Environmental Education (NAAEE, 2011 as cited in Daniš, 2013) informs us, EL includes dispositions, knowledge, and competencies applied for responsible environmental behavior. Ultimately, individuals should be aware of nature's laws and sensitive to environmental problems and communicate with nature through EL (Kaya and Kazancı, 2009). Environmentally literate individuals have social awareness about their own actions, as well as environmental awareness (Stoller-Patterson, 2012).

Ultimately, studies have shown that two general concepts of the SE and EL are related to each other for producing scientific solutions towards environmental problems; that is, EL is one of the prerequisites for qualified SE. Moreover, the reflection of the SE on the EL contributes to solving the environmental problems. Therefore, the quality of SE given the students affects the quality of the process of producing solutions to these environmental problems.

1.3. Historical Development of Environmental Literacy

Environmentally literate individuals are also capable of individually and collectively making informed decisions concerning the environment (Hollweg, Taylor, Bybee, Marcinkowski, McBeth and Zoido, 2011). The importance of EL in SE is increasing for the protection of nature. Therefore, EL is a concept that is constantly evolving. Throughout its historical development, studies on an EL framework have increased in recent years. The milestones of the historical development of EL have been summarized in Figure 1.2.

In 1969	•The concept of environmental literacy was first described (Roth, 1992).
In 1972	•Environmental education gained international acknowledgement with the Stockholm Declaration (Belgrade Charter, 1975; Wright, 2002). •It has reported on the development of environmental education.
In 1977	•The first Intergovernmental Conference on Environmental Education was convened by UNESCO in Tbilisi (UNESCO (1977) .
In 1987	•It is determined international strategy for action in the environmental education and training for youth and adults the UNESCO-UNEP International Congress (UNESCO-UNEP, 1987). •The report of 'our common future', about "sustainable development" was published by the World Commission on Environment and Development (Rees, 1990).
In 1992	•Agenda 2I programme of action for sustainable development worldwide in Rio was convened (UN, 1992).
In 1993	• The National Project for Excellence in Environmental Education was launched in US (Simmons, 2007).
In 1997	•Environmental education was referred to as education for environment and sustainability in Thessaloniki (Knapp, 2010).
In 2002	•World Summit on Sustainable Development in Johannnesburg was convened to discuss a new global deal on sustainable development (von Schirnding, 2005).
In 2005	•UNESCO launched its Decade of Education for Sustainable Development.
In 2007	•The conference, 'UN Decade of Education for Sustainable Development – the Contribution of Europe' was launched in Berlin. • 4th International Conference on Environmental Education, in Ahmedabad Education (Centre for Environmental Education, 2007).
In 2014	•The 'World Conference on Education for Sustainable Development: Learning Today for a Sustainable Future' in Japan.
In 2018	•'Project of Environmental Literacy (2017-2018)'

Figure 1.2: Milestones of Historical development of environmental literacy

In 1969, the term 'EL' was first revealed in an academic paper (Roth 1968, as cited in Roth 1992). Environmental education (EE) programs are designed to increase and nurture the development of EL throughout the lifetime of the human (Subbarini, 1998). Moreover, the main purpose of EE continues to be the development of EL (Bennett and Roth, 2015). Therefore, extensive research on EL (The Project of EL) is carried out with the support of the Ministry of National Education in Turkey and Bremen University in Germany for promoting the development of EL.

1.4. The Significance of Pedagogical Content Knowledge in Teacher Education for More Qualified Environmental Literacy:

The concept of Pedagogical Content Knowledge (PCK) introduced by Shulman (1986) remains crucial. PCK is influenced three different component knowledge: Subject Matter Knowledge, Pedagogical Knowledge and Knowledge of Context (Figure 1.3.) (Abell, 2007). One of its components, pedagogy, includes the process and practice or methods of teaching and learning, including the goal(s), values, and methods of teaching, and assessment strategies of student learning (Koehler, Mishra and Yahya, 2007). This generic form of knowledge includes that teachers with deeply pedagogical knowledge understand how their students construct knowledge, acquire skills, and develop habits of mind and positive dispositions toward learning (Mishra and Koehler, 2006). Content in PCK is the subject matter that is to be learned or/and taught (Koehler, Mishra and Yahya, 2007). Shulman (1986: 9) mentioned that;

> *"…the subject matter content understanding of the teachers be at least equal to that of their lay colleague, the mere subject matter major. The teacher need not*

only understand that something is so; the teacher must further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied…"

Therefore, content knowledge is more important for teachers and their knowledge about the subject matter to be taught (Koehler and Mishra, 2009). Moreover, they should understand the nature of knowledge and inquiry in both their field and different fields (Mishra and Koehler, 2006).

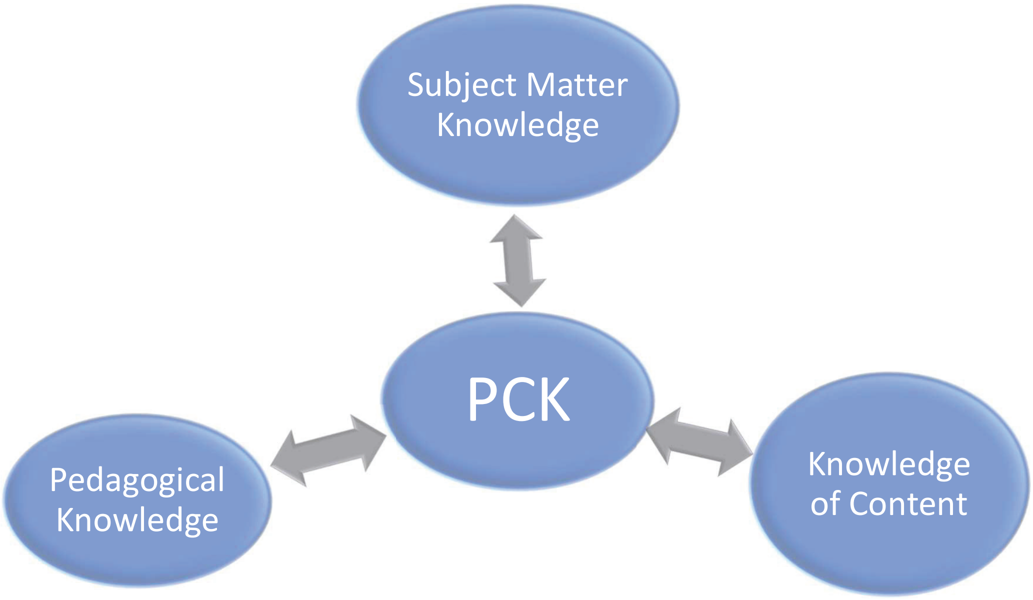


Figure 1.3. The model of teacher knowledge. In this model PCK is presented as a unique knowledge domain (van Dijk, and Kattmann, 2007: 889).

The components of the pedagogical content knowledge that should be included in the science teacher education program for science teaching are as follows (Figure 1.4.) (Magnusson, Krajcik and Borko, 1999: 125-126):

- The goals of SE and their relationship with purposes for teaching science (knowledge of orientations to teaching science, knowledge of science goals and objectives).
- Instructional strategies that match orientations to teaching science (knowledge of subject-specific strategies, knowledge of specific science curricula).
- Planning, conducting, and reflection upon teaching specific science topics, guided by considerations of students' understandings (knowledge of students' understanding, and science assessment), and the value of using instructional strategies (knowledge of topic-specific strategies).
- Planning and management of evaluations that are coherent with student's orientation to science teaching and targeted goals and objectives (knowledge of science assessment).

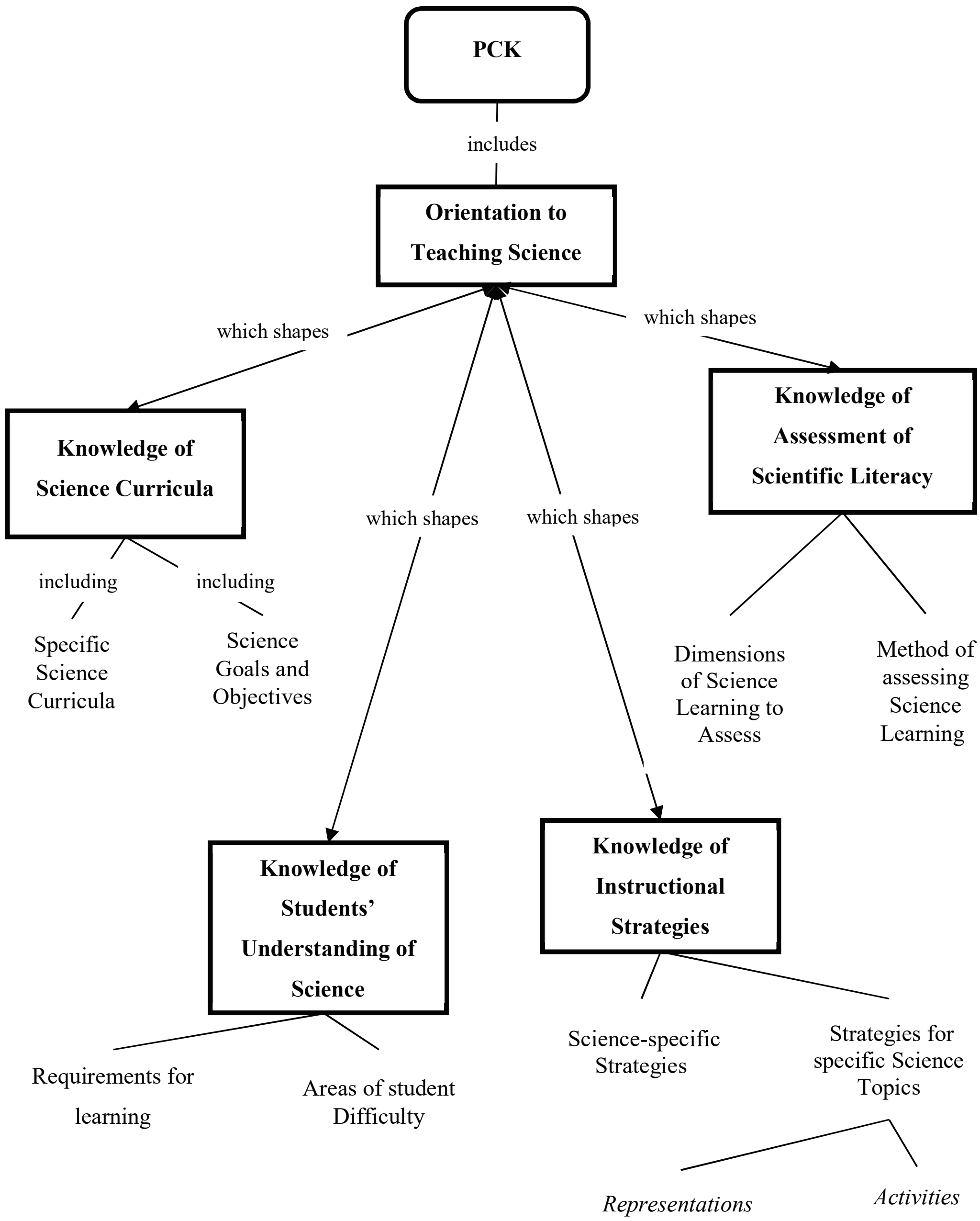


Figure 1.4. Components of pedagogical content knowledge for science teaching (Magnusson, Krajcik and Borko, 1999: 99).

Nowadays, the development of PCK and its framework continue to meet the expectations of the 21st Century. One of the most concrete examples is Technological Pedagogical Content Knowledge (TPCK) introduced by Mishra and Koehler in 2006, which integrated technology with PCK and recognized the importance of technology in education (Figure 1.5.) (Koehler and Mishra, 2009). TPCK is a structure formed by combining three different knowledge (technological knowledge, pedagogical knowledge, content knowledge) components (Mishra and Koehler, 2006).

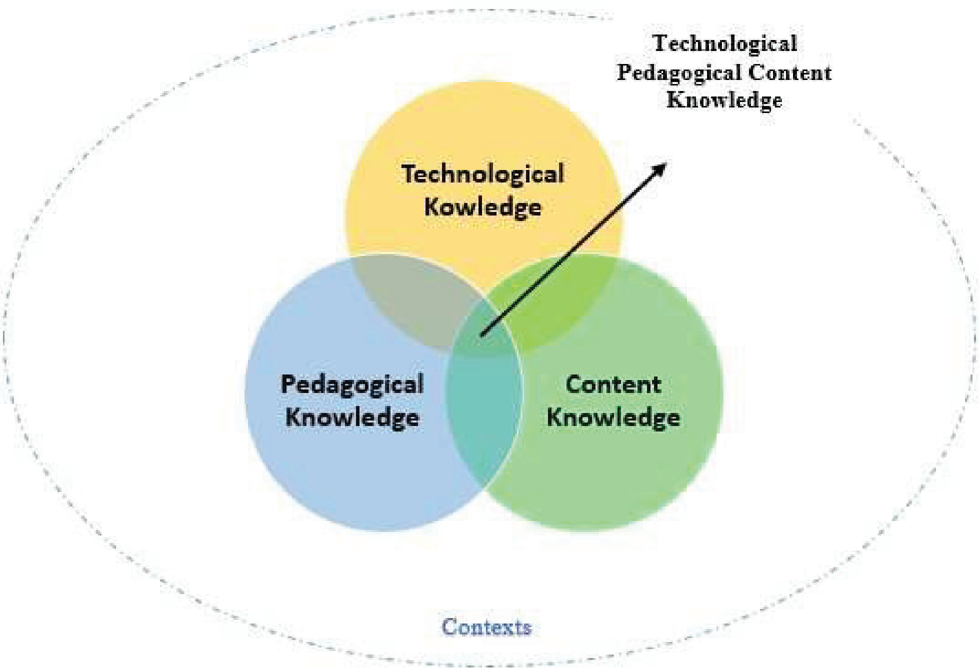


Figure 1.5. Technological Pedagogical Content Knowledge (Koehler ve Mishra, 2009: 63)

The development of TPCK by teachers is critical to effective teaching with technology (Koehler, Mishra and Cain, 2017) because TPCK is a beneficial concept for thinking about the integration of technology into teaching and how they might develop this knowledge (Schmidt, et al. 2009). Nowadays, stakeholders of education should think critically about how to integrate STEM education into science teaching with the concept of STEM starting to take place in the current science curriculum. For this reason, the importance of the relationship between STEM and PCK is emerged for fostering the teachers' professional development.

Rapidly evolving technology has quickly become a reflection of education. One of the best examples of this is STEM education. Therefore, STEM education, which is one of the important components of education nowadays, is included to science curricula. However, some questions are raised for the quality of STEM education: However, there are some questions that need to be answered for the quality of STEM education: Is STEM pedagogy (STEM teaching and learning) included in both teacher education programs and in-service teacher training? How teachers gain content knowledge (especially field of science, technology, engineering, and mathematics) and STEM knowledge (how to integrate different disciplines in STEM activities)? The level of response to these questions will indicate the STEM-PCK levels of the teachers. For this reason, in order to increase the quality of the future outcome of STEM education, it is necessary not only to integrate the STEM concept into curricula but also to increase the knowledge and experience of teachers who are curricular practitioners.

1.5. STEM Education

In the United States, increasing concern about ability to maintain its competitive position in the global economy has renewed interest in STEM education (Chen and Weko, 2009). In the recent years, the prominence of this concept has also begun to appear more and more in

Europe. That is why to educate a generation who has the necessary preliminary knowledge and skills in the fields of STEM, produce innovative solutions and think freely (Aydeniz, 2017). In order to educate qualified current and future generations, it is necessary to apply STEM-focused SE systematically and to implement the desired behavioral change in students (Kaya, 2017).

1.5.1. What does ‘STEM Education’ mean?

In the 1990s, the National Science Foundation (NSF) began using “SMET” as shorthand for “science, mathematics, engineering, and technology”, however, this abbreviation has been changed to STEM since it causes conceptual confusion (Sanders, 2009). It is seen that the STEM concept, of which popularity is increasing in Europe nowadays, emerged as MINT in Germany. The term “MINT”, an acronym for mathematics, information technology, science and technology, is predicted to fill for lack of qualified applications in the future (Wood, 2011). STEM education has actually been around for a long time in our life, but the importance of this concept has been emerged recently by legislators and educational administrators (White, 2014). The common point of SE expressed differently in different countries is aimed at effectively relating different disciplines in order to meet future expectations in the field of industry.

STEM education, which is a word that is widely used with pre-school to postgraduate students and the acronym "STEM" (science, technology, engineering, and mathematics) has provided the forefront of the statements in education, industry, innovation, and competition

(Marrero, Gunning and William, 2014). STEM education increases pupils' understanding of how things work and improving their use of technologies (Bybee, 2010). Merill (2009 as cited in Brown, 2012) determines the STEM education as follows,

> *"A standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline specific content is not divided, but addressed and treated as one dynamic, fluid study."* (Brown, 2012:7)

STEM education perspective includes viewing the separate disciplines of science, technology, engineering, and mathematics as one unit, therefore, teaching the integrated disciplines as one cohesive entity (Breiner, et al, 2012).

1.5.2. The Importance of STEM Education

STEM education has the opportunity to integrate four disciplines into a coherent teaching and learning paradigm, as well as providing students with the best opportunities to make sense of the world holistically (Lantz, 2009) because, STEM education offers students the opportunity to realize their own potentials, improve their strengthen self-efficacy and STEM education supports them through their social and academic integration (Elster, 2014). STEM Education focuses on development of students' skills such as 21st-century skills, innovation skills, cooperative learning and teamwork, problem-solving (Flanders State of Art, 2018).

Moreover, quality of STEM education is crucial for the future achievement of individuals (Stohlmann, Moore, and Roehrig, 2012). Therefore, the interest and motivation of students for STEM should be increased in order to improve the quality of STEM education and to improve their skills more effectively in the field of STEM. Things to do for increasing their interest and motivation of STEM (National Science Foundation, 2011) are listed below:

- Relate science to students' daily lives,
- Employ hands-on tasks and group activities,
- Use authentic learning activities,
- Incorporate novelty and student decision-making into classroom lesson,
- Ensure that STEM curricula focus on the most important topics in each discipline.

One of the important factors that affect the quality of the Industrial 4.0 Revolution is related to the quality of STEM education to be given to the students. The importance that the countries place emphasis on STEM education in their SE systems will contribute to the knowledge and skills required by the industrial revolution.

1.5.3. STEM Education and Industry 4.0: Example of Germany

It is necessary to foresee the areas of business that will meet the expectations of the present and future century and to take steps in this direction for the sustainable economic developments of countries. For this reason, governments are investing not only in the industrial sector but also in the educational area continually. Nowadays, STEM education is one of the best examples. It is one of the concepts that are important in the field of industry 4.0 in order to improve the quality of the workforce. The increase in the workforce quality in countries also contributes to the increase in the efficiency of the industry 4.0. As seen in the figure 1.6, United States, Japan, Korea and China are in the foreground in the ICT technologies field in 2012-2015; a few European economies, namely Sweden, Germany and France, also featured among the top leaders of some bursting ICT fields (OECD, 2017).

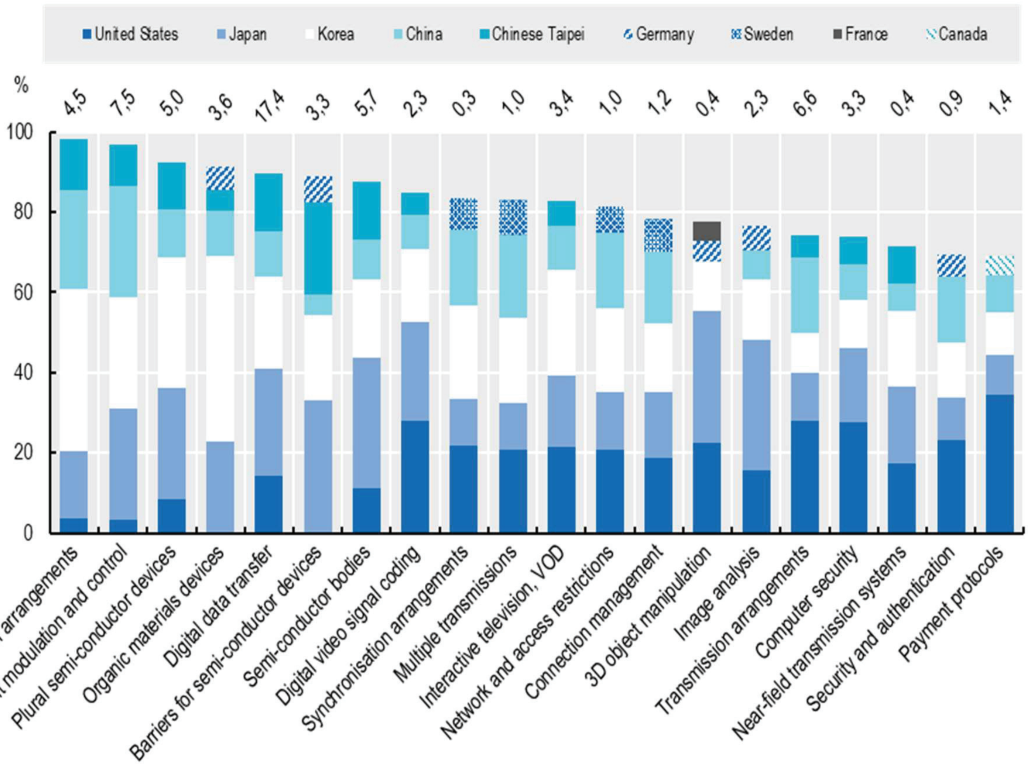


Figure 1.6. Top players in emerging Information Communication Technologies, 2012-15 (OECD, 2017: 20)

In figure 1.7, there is information about patent application on artificial intelligence in different countries. According to OECD (2017), in 2015, Japan, Korea and the United States account for over 62% of Artificial Intelligence (AI) -related patent applications during 2010-2015, down from 70% in 2000-2005. Over the same period, Korea, China and Chinese Taipei increased their number of AI patents compared to rates observed in 2000-2005. EU-28 countries contributed to 12% of the total stock of AI-related inventions in 2010-2015, down from 19% in the previous decade.

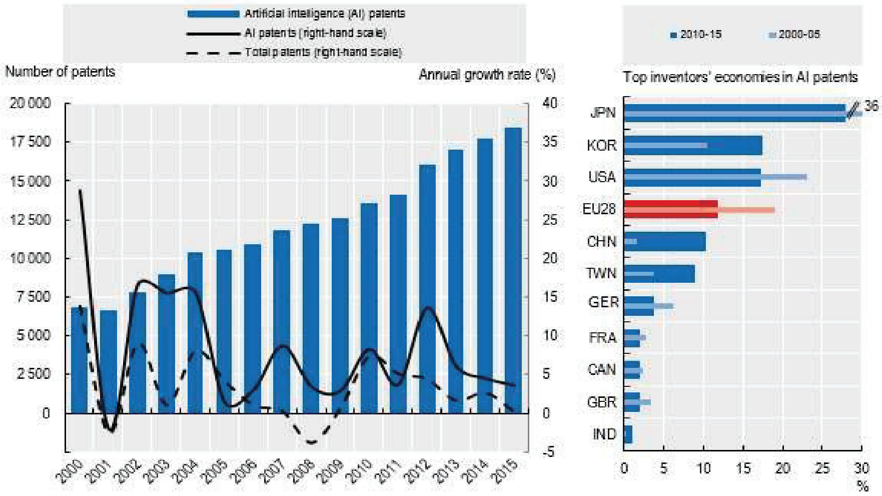


Figure 1.7. Patents in artificial intelligence technologies, 2000-2015 (OECD, 2017: 22)

Research in the field of AI has aimed for decades to allow machines to perform human-like cognitive functions (OECD, 2017). During 2006-2016, as seen in figure 1.8, America is the country which has the most researches and citations about the machine learning. Moreover, it is observed that both the number of publications and the number of citations in Germany increased from 2006 to 2016.

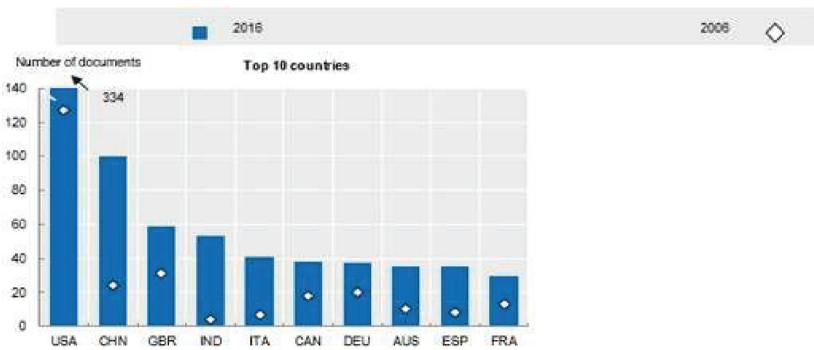


Figure 1.8. Top-cited scientific publications related to machine learning, 2006 and 2016 (OECD, 2017: 25)

In figure 1.9, some countries in Europe have been informed about high-tech exports in different areas. When figure 1.9 is examined, it can be seen that approximately 25 % of German exports is electronics-telecommunications and 20% is computers-office machines. When we consider that exports in Germany are about 45% technology-oriented, therefore, it can be said that the pace of industry 4.0 revolution will contribute to the strengthening of the economy.

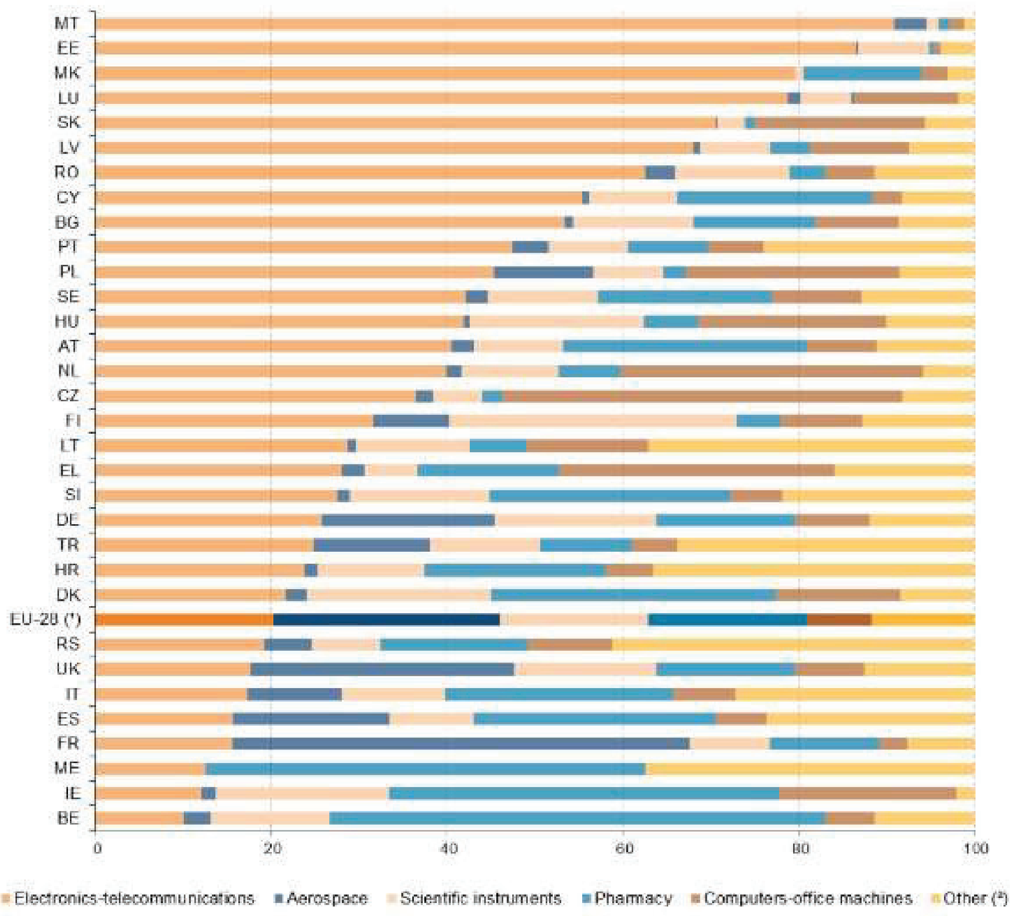


Figure 1.9. High-tech exports by high-technology group of products, EU-28 and selected countries, 2014 (in %) (Eurostat, 2016)

Table 1.2 shows the total imports and exports of Germany and European Union between 2014 and 2017.

Table 1.2. High-tech trade by high-tech group of products in million Euro (Eurostat, 2018)

Year		European Union	Germany
2014	Imports	335,3 Million Euro	76,2 Million Euro
	Exports	347,7 Million Euro	83,8 Million Euro
2015	Imports	364,8 Million Euro	80,9 Million Euro
	Exports	379,2 Million Euro	91,4 Million Euro
2016	Imports	366,3 Million Euro	82,1 Million Euro
	Exports	385,3 Million Euro	93,1 Million Euro
2017	Imports	397,0 Million Euro	83,3 Million Euro
	Exports	413,7 Million Euro	96,9 Million Euro

As seen in Table 1.2., Germany's imports and exports are constantly increasing as it is in the European Union. Moreover, when figures 1.10 and 1.11 are examined, it is observed that in Germany, both technological and sectoral developments have increased both in the sector and in the whole of these sectors. The largest increase in the sector is in the robotic area.

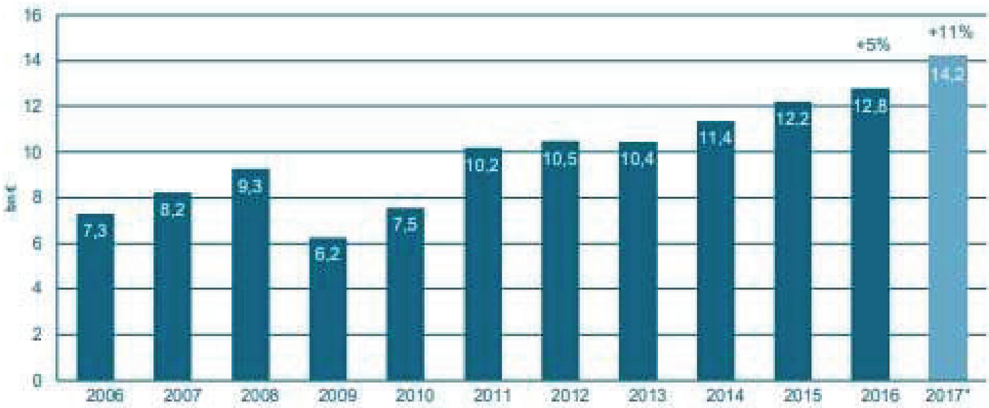
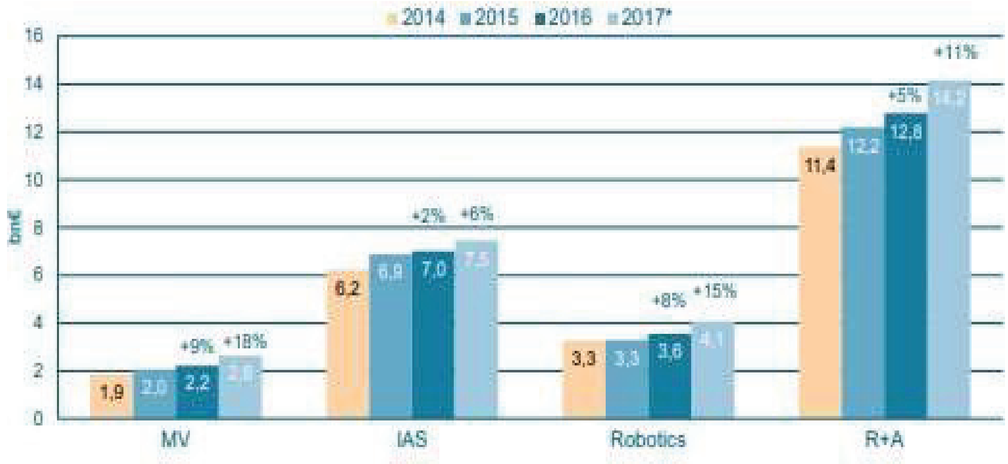


Figure 1.10: Robotics and Automation Germany Total Turnover (VDMA, 2017:2)



* forecast; robotics (R); automation (A); machine vision (mv); integrated assembly solutions (iAS)

Figure 1.11: Total Turnover Robotics and Automation Germany by sectors (VDMA,2017: 2)

As a result, the interest in industry 4.0 will increase with each passing. Therefore, industrial sectors concentrate more on the production of technological tools that will meet the needs of industry 4.0. Also, in the field of industry 4.0, there is a need for individuals with innovative and 21st-century skills to achieve economically desirable achievements. Education systems have great responsibility to educate individuals with innovative and 21st-century skills. Nowadays, STEM education is one of the educational reforms carried out to overcome this responsibility. Policymakers in the field of education think that they will be better able to adapt to the development of industry 4.0 through STEM education. Countries might increase their economic strength globally if they have achieved the desired success in the field of the STEM. This success might lead to an increase the socio-economic welfare of people.

On the other hand, in order to reach industry 4.0 targets, one of the things that we should not ignore is to avoid the rapid depletion of existing natural resources and not to allow technological wastes to pollute the World quickly. For this reason, while educating individuals who will meet the expectations of the 21st Century through STEM education, they should also be educated to be individuals who know how to protect and use nature and natural resources. Therefore, the concept of the ‘environment’ is actually a core concept in STEM education.

1.6. Science Literacy in Respect to the Environment: CHALLENGES

International student assessments like Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) provide significant information about SE policies, programs, and practices in different nations (Bybee and McCrae, 2011). Therefore, SL is constantly evolving. The most concrete example is the changing definition of SL. However, when the changes in the framework and definitions of SL are considered, is there a consensus that SL is adequately covered in the definitions and framework of the environment? Since it does not provide a common view on this question by experts, EL and its development should be one of the future discussions about SE. Moreover, the concept of EL should become a universal value, since all humanity has a responsibility for the protection of natural life. For this reason, international assessment research should be able to evaluate EL directly to promote the development of EL universally. By this means, outcomes related to EL might be obtained globally and awareness of the protection of nature and natural life might be raised about taking responsibility for the countries.

While countries take responsibility for the education of more qualified environmental literate individuals, one of the problems that may arise will be the effectiveness and efficiency of the reforms that will take place. The development of more environmentally friendly science curricula and integration of the contemporary concepts related to EL into both teaching process and teacher education seems to be an easy process, however, the practice of the new reforms is a challenging process. For this reason, countries will be able to come up with this difficulty more easily by universal cooperation and common purpose.

1.6.1. International Assessment of Environmental Literacy with Large-Scale Studies

Scientific literacy is of paramount importance to national and international assessment in SE. For example, PISA includes items directly related to SL. However, although its scientific literacy tasks include items related to environmental issues, it does not evaluate EL directly. A literature review found international empirical research on students' EL (Fah and Sirisena, 2014; Spínola, 2015) and the EL of teachers and teacher candidates (Pe'er, Goldman and Yavetz, 2007; Tuncer, et al, 2009; Yavetz, Goldman, and Pe'er, 2009; Derman, Sahin, and Hacieminoglu, 2016). Researchers have developed scales to assess EL (Ozsevgec, Artun, and Ozsevgec, 2010; Atabek-Yigit, et al, 2014). However, it seems that there is not enough research on EL using large-scale assessments. Therefore, in the future, international educational committees should take more responsibility to assess the EL. For example, PISA might provide an opportunity to survey EL in different nations. It is a good opportunity to enrich the universal meaning of EL to produce solutions to global environmental problems.

1.6.2. The Necessity of Updating of the Environmental Literacy’s Framework

Human needs increase day by day. This situation has positive and negative effects on the environment both directly and indirectly. However, it is necessary for individuals to be more sensitive to the environment to reduce the negative effects. This necessity also obliges the change in and development of the concept of EL. For this reason, studies continue to revise the components of EL and to promote EL (Disinger and Roth, 1992).

In addition to educating qualified environmental literacies, current and potential future environmental problems as well as their possible solutions are included in science curricula and textbooks to raise awareness. The environmental problems are explained to allow learners to understand the importance of issues of the natural environment. For this reason, environmental field experts and environment education provide an opportunity for researchers to determine what environmental issues should be addressed and how those issues should be explained in science curricula and textbooks.

The framework of EL and its influences are key issues in science teaching. Therefore, when preparing curricula or textbooks, the concept of environment should be presented with a broad perspective. Science curricula and textbooks that address EL may also provide opportunities to protect the natural environment and promote its effective use. Furthermore, science curricula and textbooks may be educational tools that help individuals learn concepts related to the natural environment and to put them into practice.

Moreover, nowadays, the relationship between engineering and environmental systems is increasing in importance, which is recognized in SE and curriculum development in the field of Science, Technology, Engineering, and Mathematics (STEM) education. There is a need for further research about how individuals are influencing environmental systems (Tsurusaki and Anderson, 2010) and how to integrate engineering and environmental systems effectively.

1.6.3. The Significance of Qualified Teacher Education in respect to Environmental Literacy

Pedagogical knowledge is used to facilitate effective teaching practices in ways that aim to make learning more accessible to students (Hudson, et al, 2015). When pedagogy is most successful, faculty and students work together toward the shared purpose of learning (Association of American Universities, 2018).

One of the things to be aware of for the quality of EL is teacher education because the quality of the teacher education may directly affect the education of environmental literate individuals. Teacher content knowledge is one of the paramount elements of the improvement of teaching and learning (Ball, Thames, and Phelps, 2008). Therefore, teachers should be supported to increase their experience in teaching and learning, not only in preservice but also in in-service training. In order to increase knowledge and experience of teachers and educators in teaching, EL should be integrated into the PCK.

1.6.4. Science Education Reforms without Neglecting the Concept of Environment

It is already predictable that technology will develop faster with the industry 4.0 revolution. This means that existing natural resources will be exhausted more quickly. Therefore, future generation should be aware of necessity of the environmental protection while developing and using the technology. This awareness may contribute to the reduction of daily waste as well as commercial waste especially industrial waste including waste batteries, electrical and electric materials, etc.

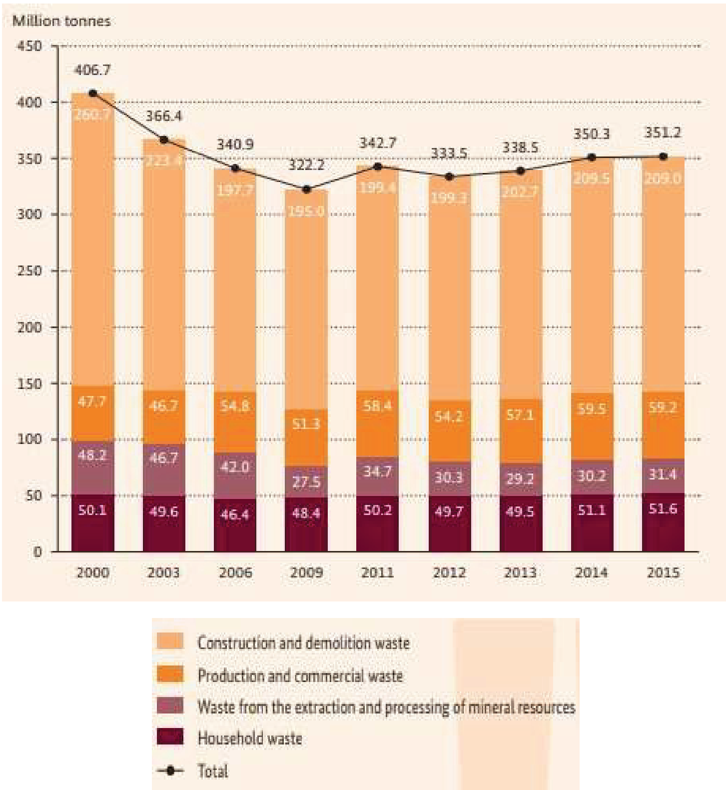


Figure 1.12. Waste generation in Germany 2000 – 2015 (Federal Ministry for the Environment, 2018: 7)

As seen in figure 1.12, especially after 2012, the total amount of waste seems to increase continuously. This means that existing resources need to be protected in order to avoid a faster increase in the amount of waste. In addition, increasing the recycling awareness of these wastes also contribute to the reduction of waste materials. As seen in figure 1.13, the disposal rate is also decreasing as the recycled amount increases.

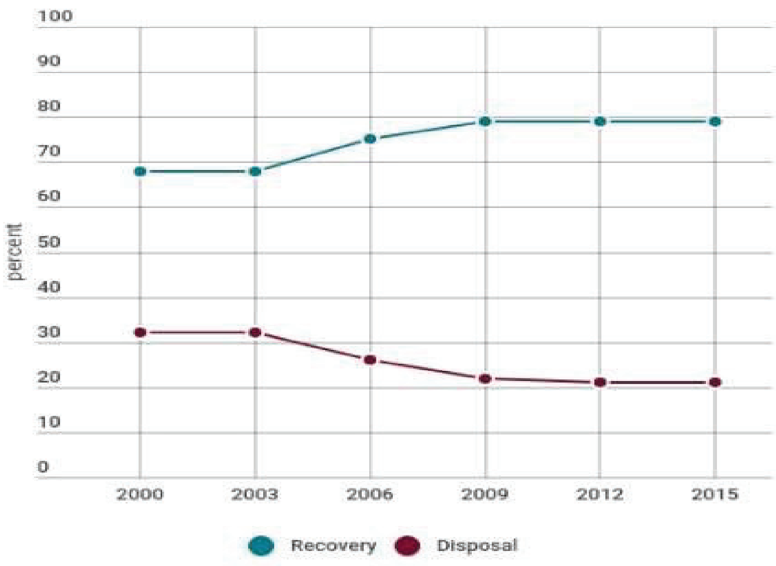


Figure 1.13. Recovery and Disposal Rates 2000-2015 (Federal Ministry for the Environment, 2017:1)

In particular, it is necessary to take into account that the production and commercial wastes are increasing at certain intervals, and the wastes such as waste batteries, electrical and electric types of equipment will be increased even more with industry 4.0. Preventing the increase of this amount of waste more rapidly will mean the protection of existing resources. We have the obligation to educate future generation as environmentally conscious individuals, and to consider the harms of science and technology on the environment (Aydeniz, 2017). For this reason, the importance of 'environmental' in STEM Education should be revealed. In this regard, teachers and researchers have a great responsibility because, during STEM education, it is necessary for practitioners to reveal the importance of the environment and how to integrate the environmental issues into STEM education.

1.7. Definitions of The Terms

Environmental Literacy: The environmentally literate person communicates and applies major ecological concepts and principles, and understands how man's activities influence the environment from an ecological perspective demonstrates the ability to identify and investigate environmental issues and alternative solutions, and assimilates environmental values needed for rational and responsible use of environmental resources (Subbarini, 1998: 245).

Science Literacy: The ability to play a role in scientific matters as a reflective citizen with scientific ideas. A person with sufficient scientific competency is willing to take part in a reasoned and scientific and technological discourse requiring the scientific explanations of scientific matters, evaluation of scientific research and its design, and scientific interpretations of data and evidence (OECD, 2016: 20).

Education for Sustainable Development: UNESCO is the lead UN agency for Education for Sustainable Development (ESD) and is responsible for the overall management, coordination and implementation of the Global Action Programme on ESD. Moreover, UNESCO supports countries to develop and expand educational activities that focus on sustainability issues such as climate change, biodiversity, disaster risk reduction, water, cultural diversity, sustainable urbanization and sustainable lifestyles through ESD (UNESCO, 2018).

STEM Education: STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009, as cited in Gerlach, 2012).

Pedagogical Content Knowledge: Pedagogical content knowledge (PCK) includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners. Therefore, PCK also includes the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in other words, the ways of representing and formulating the subject that make it comprehensible to others (Shulman, 1986).

1.8. Key Message

Issues
• Nowadays, individuals, who are sensitive to the environment, are more needed for more sustainable development. • EL should be universally valued. Therefore, it should be more sensitive to the concept of EL in SE to find the solution to the problem of rapid raw material consumption at the optimum level. • Primarily, EL of students should be determined by international studies in order to add universal value to environment literacy. • Opinions of the experts on how to reform in the education especially fields of SE should be taken with the goal to update the educational system, curricula, and textbooks in this direction. • In the process of teachers' professional development, teacher candidates and teachers should focus on both content and pedagogical knowledge about how to teach environmental subjects.
Challenges
• Science curricula, textbooks, and teacher education should be revised to integrate the EL. • Common universal values should be developed in respect to the environment for individuals and the society. • New educational reform(s) should be discussed in order to educate more qualified environmental literate individuals.

Chapter 2. Introduction and Methods

In this chapter, 'the research problem and questions', 'the aim of study', 'the significance of the research' and 'limitations' are included.

2.1. Research Problem

Individuals with their decision related to the environment, which in they live, should be aware of their effect on nature. Avoiding negative attitudes and behaviors towards the environment, individuals are expected to make an important contribution to making the world more livable. More environmental literate individuals are needed. Also EL is rising significantly for a more sustainable development. Therefore, societies, in which individuals come together, and governments, in which the societies come together, with environmental awareness have more responsibility to the environment for the development of EL nowadays. Governments should consider the importance of EL in their own education systems and reform the education system for a more sustainable future. It should be demonstrated in national studies as well as international studies to evaluate the quality and contributions of these reforms in the education system. However, when the framework of PISA is examined, even through its scientific literacy tasks include items related to environmental issues, EL is not evaluated directly (Kaya and Elster, 2018a).

Researchers should demonstrate the importance and benefits of involvement of EL in international assessments. In the circumstance, it might enable to include the concept of EL into the framework of further large-scale assessments. By examining the outcomes of these international assessments, researchers might be able to identify and address the negative effects of EL in-education systems and to develop solutions. Moreover, they might also be able to compare the results of different countries with each other. They might be able to find out successful practices related to EL in their education systems or/and different countries' education systems. As a result, further research is needed to improve the quality of the EL. If EL is involved within the framework of international studies, there might be an increase in research on EL from an international perspective.

2.1.1. Research Questions

In this part, the research questions are included about research Field-I and Field-II. It is also comprised the sub-questions related to studies.

Research Field-I: Large-Scale Assessment

Study (1)

The main aim of this research is to determine the factors that affect the EL of 15-year old students in Germany. More specifically, its research questions are:

- Which factors affect EL of 15-years old German students?

- What is the relationship between EL and SEC of the students (such as type of books and number of musical instruments at home)?
- What is the relationship between the EL and TC (such as explanations, individualized help and the structure of lessons)?

<u>Study (2)</u>

In conducting study-2, the main aim is to determine the change in the EL of German pupils from 2006 to 2015. More specifically, the research questions investigated in this study were:

- What factors influence EL?
- In what way do the EL factors (development of environmental behaviour, environmental awareness and environmental responsibility) change from 2006 and 2015?
- How does the change in the influence of students' attitudes towards science (such as enjoyment of science, interest in science) impact EL from 2006 to 2015?
- What changes occur from 2006 to 2015 in the influence of teaching methods for lessons on EL?

<u>Study (3)</u>

The purpose of study-3 is to determine the variance of the main factors affecting the environmental literacy of the fifteen-years-old students in Germany, Singapore and Estonia. Within the scope of this aim, answers to the following questions were sought:

- What are the main factors influencing the environmental literacy of the students in the age group of fifteen in Singapore, Estonia and Germany?

- How is the similarity between countries considering whether they are statistically significant or not?
- How much of the explained variance of the students' perceptions of environmental literacy averages is explained by the main factors covered in this research? How are the rates of disclosure compared to the countries?

<u>Study (4)</u>

In study-4, one of the main aims of this paper is to determine the dimensions (effects of family, teacher, student, and teaching) that influence the environmental literacy. Moreover, another aim is to analyse the effects of environmental perceptions on science education through science literacy. In these regards the research questions are:

- What are the dimensions (effects of family, teacher, student, and teaching) influencing the Environmental Literacy (EL) of the German students?
- How much of the explained variance of the Environmental Literacy averages is explained by the dimensions covered in this research?
- What are the environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) influencing the Science Literacy of the German students?
- How much of the explained variance of Science Literacy averages is explained by the environmental perceptions covered in this research?

Research Field-II: Delphi Studies

Study (5)

The goal of study-5 is to clarify the framework (concepts, contexts, and competencies) of environmental literacy and to reach consensus on this framework based on expert opinions. Within the scope of this aim, answers to the following questions are sought:

- How do experts define environmental literacy?
- Which concepts and contexts are included in the framework of environmental literacy? And which teaching methods and extra-curriculum activities are used for the development of environmental literacy?
- What are the competencies of the environmentally literate individual?
- Who is responsible for the development of qualified environmentally literate individuals? And what should be done to promote the development of environmentally literate individuals?

Study (6)

In study-6, the main goal is to determine teachers' experiences and qualifications as environmental STEM literate individuals for the development of environmental literacy in accordance with expert opinions. The sub-question is:

- What teachers should do their experiences and qualifications as environmental STEM literate individuals for development of environmental literacy?

2.2. Aims of Dissertation

One of the aims of this study is to determine the factors that influence the EL and to compare the EL of countries. The second purpose is to identify the consensus of experts on EL to revise the definition and framework of EL. The last goal is to integrate the concept of the environment into teacher education and STEM education. The aim of the study is divided into specific 2 stages in order to present information about the purpose of the thesis in more detail.

2.2.1. Aim of Large-Scale Assessment (PISA) Studies

One of the main aims of the study is to both determine the factors that affect EL of German students and compare the factors that influence the EL in the different countries. Another purpose is to determine the effects of environmental perceptions on SL. In the last part of study, it is also tried to revise the EL framework in line with expert opinions.

In line with the main aims, in study-1 and study-2, it is determined both 'the factors that affect the EL of 15-year old students in Germany', and 'the change in the EL of German students from 2006 to 2015' respectively. The purpose of study-3 is to compare the variance of the main factors affecting the EL of fifteen-years-old students studying in Singapore, Estonia and Germany. The aim of study-4 using PISA data is to determine both 'the dimensions (effects of family, teacher, student, and teaching) that influence the EL', and 'the effects of environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) on SL'.

2.2.2. Aim of DELPHI Studies

After the quantitative researches using PISA data, it is aimed at reaching consensus of experts on the framework of EL with Delphi Study (study-5). The purpose of study-5 is to redefine and revise the concept of EL based on expert opinions. Thus, changes for the definition of this concept will be put forward and suggestions to achieve increased EL will be presented.

In a further Delphi study (study-6), the main goal of the research is to determine 'what teachers should do to promote their experiences and qualifications as environmental STEM literate individuals' in accordance with expert opinions. Study-6 also aims to demonstrate the necessity of integrating the concept of environment into STEM and teacher education. In this study, literature reviews and solution proposals on STEM education and pedagogical knowledge are presented in order to integrate the concept of the environment into current education reforms especially STEM and teacher education.

2.3. Significance of the Study

Nowadays, individuals who are sensitive to the environment are more needed for more sustainable development. In other words, educating qualified environmental literate individuals will mean nature protection and more thrifty use of existing natural resources. Educating and being qualified environmental literate individuals is not only the responsibility of certain societies or countries. But everyone who lives in the world is also responsible. EL should be universally valued. Therefore, there is a need for comprehensive and detailed research on EL.

The first importance of the research field emerged from the need to conduct a comprehensive research on EL. Therefore, it was tried to determine the EL and the factors affecting EL. In addition, in 2005, UNESCO launched its Decade of Education for Sustainable Development (2005-2014), focusing on educating more qualified individuals for a more sustainable future. There was an opportunity to present the results of the changes in the EL of German students before and after the implementation of this Decade of Education for Sustainable Developing by analysing PISA 2006 and 2015 data. Moreover, it was determined and compared the variance of the main factors affecting the EL of the fifteen-years-old students in three countries (Germany, Singapore, and Estonia). The positive environmental practices of different countries in SE may contribute to the future generations' awareness towards nature. A comprehensive result on EL has been achieved through using PISA data.

The second importance of the study emerged from the need to revise the EL in science curricula, textbooks, and teacher's professional development to develop common universal value for individuals. Therefore, after the outcomes obtained fom the PISA studies, the Delphi studies have provided detailed results on the new definition and framework of EL in the light of experts' opinions. A consensus of experts has been reached in the definition and framework of the EL in order to revise EL. Policy makers and curriculum developers have proposed solutions concerning the development of the qualified EL for more sustainable development. In addition, in direction of experts' consensus, the need and importance to integrate the concept of the environment into new educational reforms (especially STEM education, which is being implemented in SE) and teacher education has emerged to educate more qualified environmental literate individuals. Therefore, the theoretical background for the integration of the concept of environment into STEM education and teacher education has been established. The new model has been developed to contribute to STEM teaching and the professional development of teachers. The new model is also important for new research to guide the development of STEM education and teacher education.

In conclusion, this thesis might be considered to be an important study in SE, since it includes both the factors affecting EL, and its revision, and integration EL into STEM education and teacher education.

2.4. Limitations

In this study, not only quantitative methods but also qualitative methods are used. The limitations of quantitative studies have been tried to be solved by utilising the mixed method (both quantitative and qualitative methods). Inevitably, there are some limitations that cannot be controlled during the research process. Therefore, the results of the research are valid for the following limitations:

1. Quantitative studies are conducted using German data obtained from PISA 2006 and 2015. Therefore, PISA 20106 and 2015 are limited to the variables included in student questionnaires.
2. Sampling of the study-3 is consisted of the German students as well as Singaporean and Estonian students who participated in PISA 2015.

3. Mixed research is carried out with the participation of experts in EE by means of purposive sampling.

2.5. Methods and Research Method Design

Pragmatic Paradigm is adopted as philosophy when research approach is determined. As seen in figure 2.1, as research design, sequential mixed method which is one of the mixed methods designs, is used. A mixed method is to base knowledge claims on pragmatic grounds and it provides an opportunity for researchers to use many approaches to collect and analyze data rather than subscribing to only quantitative or qualitative (Creswell, 2003). Therefore, Onwuegbuzie and Leech (2004) mention that it is possible to create easily more specific and complex designs by using the mixed method approach. Both qualitative and quantitative methods are also used as research methods.

In this process of dissertation (two research fields including six studies), firstly the four studies based on PISA data are designed as quantitative research. After the quantitative studies, Delphi studies are carried out which include both qualitative and quantitative studies respectively. With the Delphi studies, it is about the gathering of information or opinions from a wide range of experts, as well as, experts are informed of potentially useful opinions from other experts (Post, Rannikmäe and Holbrook, 2011). While quantitative research is adopted in the PISA studies (Research Field-I. Large-Scale Assessment), it is preferred to use an exploratory sequential mixed method which is one of the mixed method designs in the Delphi studies (Research Field-II).

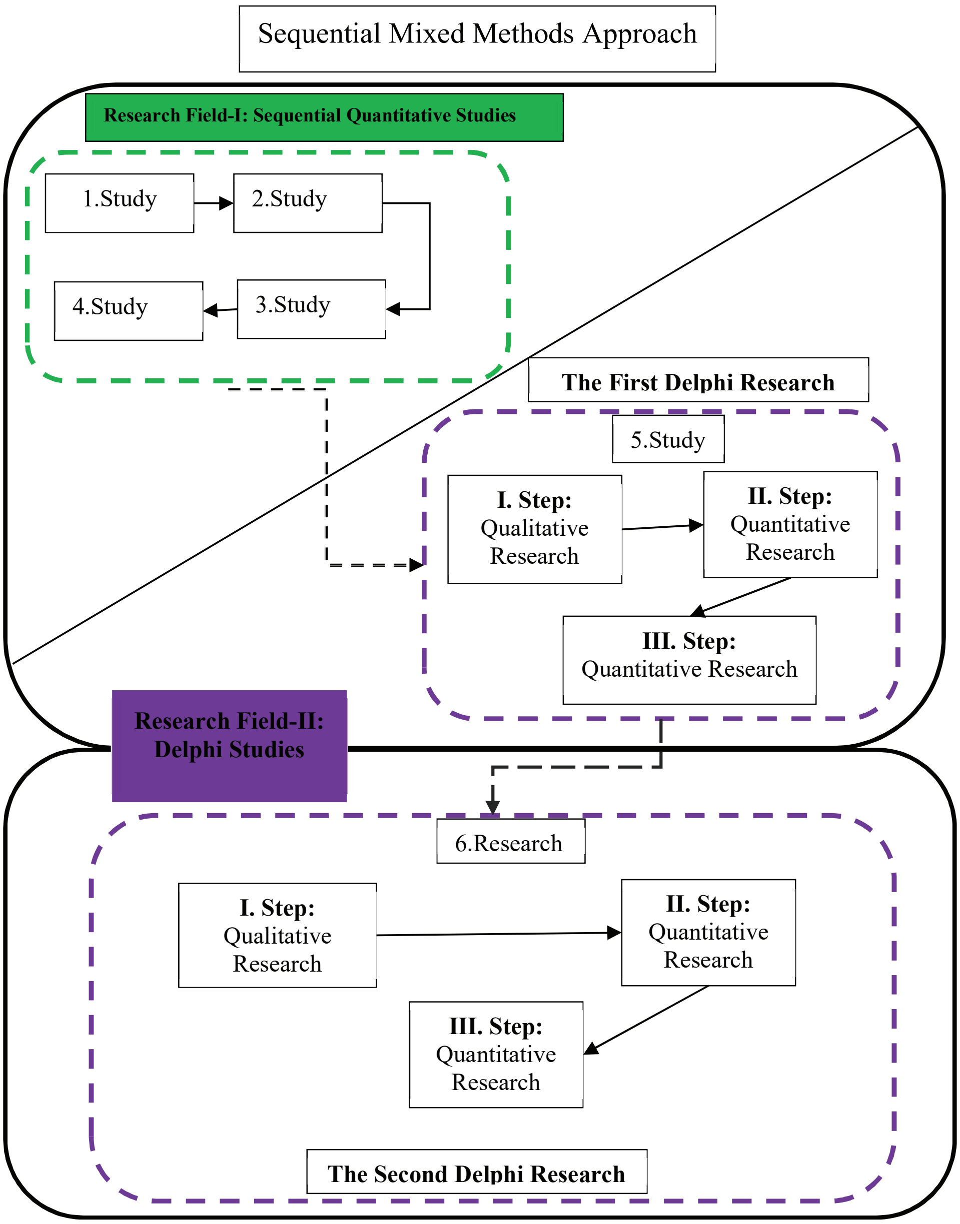


Figure 2.1.: Research Method Design

Figure 2.2 summarises the research methods in more detail. In the first research field, studies-1 and-2, the factors affecting EL are tried to be determined through the descriptive research method. In these studies, statistical analyzes such as ANOVA and t-test as well as factor analysis are used. In the Studies-3 and-4, the main dimensions affecting the environment and the SL are tried to be determined by the regression analysis through using the relational model.

In the research Field-II related to Delphi studies, it is tried to be revised the framework of the EL and to determine what teachers should do for their experiences and qualifications as environmental STEM literate individuals in line with the opinions. In the first step of the Delphi studies, structured open-ended questions and interviews are used through qualitative method, in the second and third steps of the Delphi studies, the questionnaires with the likert-type are used through quantitative method.

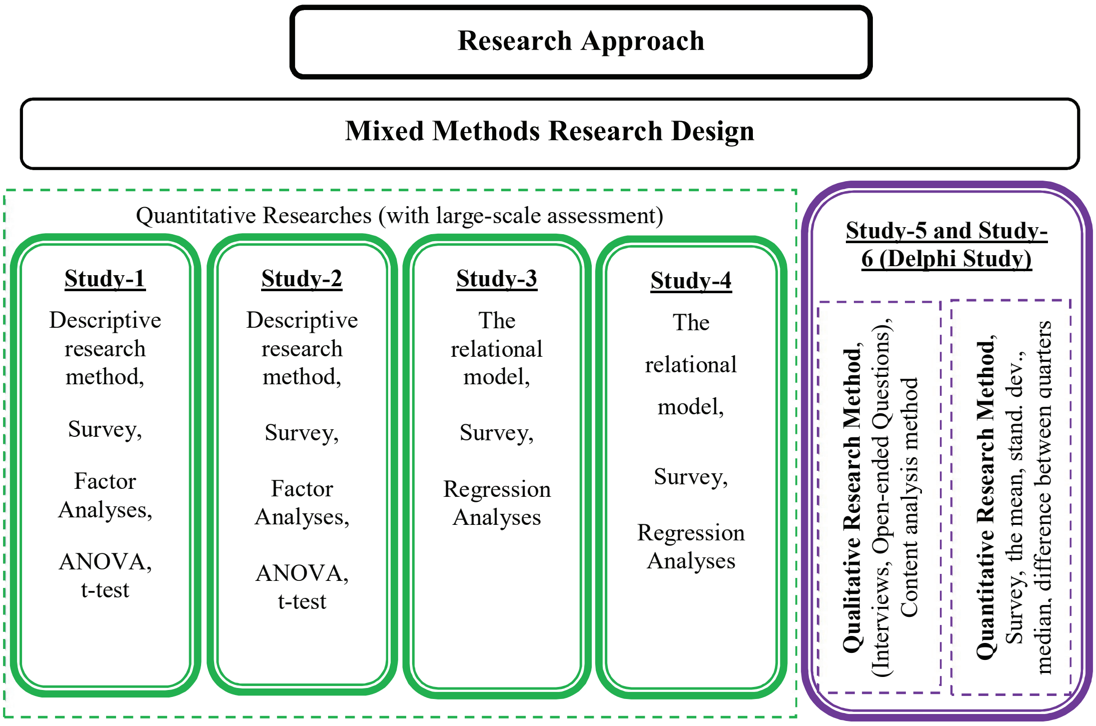


Figure 2.2.: Summary of Research Approach

As a result, it is aimed to carry out a more comprehensive and detailed study on the concept of EL by using quantitative as well as Delphi study consecutively. Moreover, it has revealed that the solutions increase the quality of current science curricula and teacher education system in the light of the obtained from results of PISA and Delphi studies.

2.6. Sampling

In the Research Field-I related to large-scale assessment, PISA 2015 data has been obtained from the official PISA web site (http://www.pisa.oecd.org). In the study-1, the target population is 15-year-old German school students. Its sample consists of 6,504 students. In the study-2, the sample population is restricted to 15-year-old German students who were attending school in either 2006 or 2015. The study sample includes 4891 pupils from 2006 and 6504 pupils from 2015, determined using PISA data from both 2006 and 2015. In the study-3, the universe is 15-years-old German, Singaporean and Estonian students. The sample consists of 6.500 German students, 6.115 Singaporean students and 5.587 Estonian students. In the study-4, the universe is 15-years-old German students. The sample consists of 6.504 German students.

In the research Field-II related to Delphi studies, 45 experts who work as a scientist/an educator/a teacher in countries of the European Union and candidate countries of the European Union (40), the United States and Africa (5) agreed to participate. However, the numbers of the participants in the 1st, 2nd, and 3rd Delphi study steps were 20, 44, and 31, respectively.

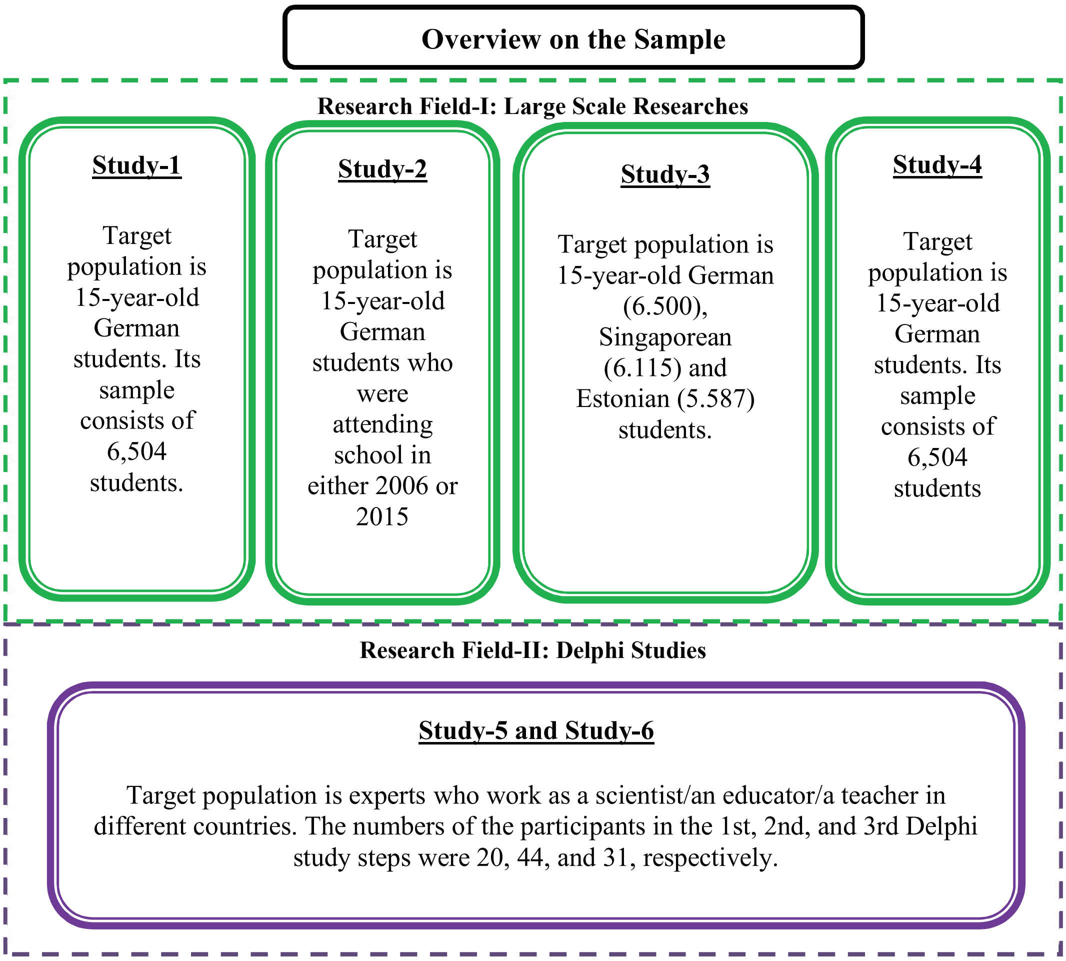


Figure 2.3: Overview on the sample

2.7. Overview of Dissertation: Reflection on Environmental Literacy

In the first research field, the target sample is 15-year-old school students in Germany, Estonia, and Singapore. In the second research field, the target sample is the experts. Additionally, issues related to the science curricula, textbooks, and teacher education are also included in the scope of the second research field to elaborate the framework of EL in a broad perspective. By this means, issues and challenges related to EL are tried to be addressed with the detailed and comprehensive view.

As seen figure 2.4, in the first of research field, there are consecutive four studies based on PISA data. In the study-1, the factors affecting EL are identified. In the study-2, changes in EL between 2006 and 2015 are determined. In the study-3, main determinants affecting EL are tried to be determined and compared among different countries. In the study-4 which is the continuation of the third research, main dimensions affecting EL, and environmental perceptions influencing SL is determined. In summary, the first research field demonstrates that it can be assessed through large-scale assessment studies. Additionally, it is tried to determine EL of students and to add universal value to EL with PISA.

In the second of research field, the framework of EL is tried to be revised with the Delphi studies. This field includes two Delphi studies. The purpose of first Delphi study (study-5) is to identify experts' views concerning EL and to reach consensus on this framework in accordance with expert opinions. Therefore, the effective solutions to the reforms in science curricula, textbooks, and teacher education are proposed. The aim of the second Delphi study (study-6) is to determine what teachers should do to develop their experiences and qualifications as environmental STEM literate individuals and to reach consensus on this framework in accordance with expert opinions. Moreover, it is concluded that nowadays STEM education and the concept of the environment should be integrated into the teachers' professional development programs. The theoretical solution to integrate the concept of the environment into STEM education and teacher education is presented. In order to educate more qualified individuals, a new model is developed for teachers' pedagogical content knowledge on how environmental issues should be taught with STEM education. The environmental STEM education and environmental STEM pedagogical content knowledge are identified.

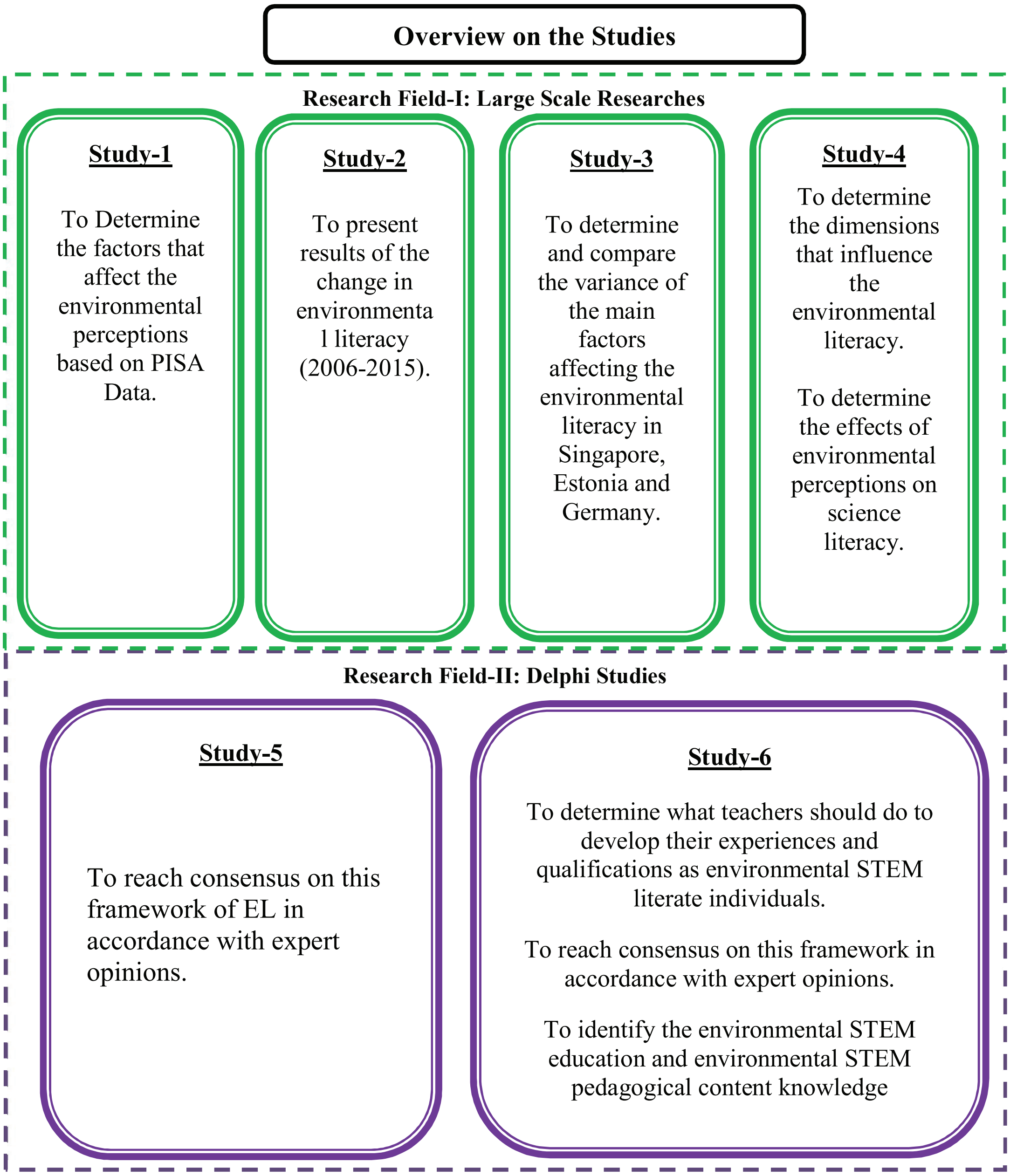


Figure 2.4: Overview on the studies

As a result, the dissertation researches on the EL with broad perspective by using a PISA data which is one of the large-scale researches. Additionally, it determines what teachers should do to develop their experiences and qualifications as environmental STEM literate individuals. In the light of these studies, it integrates the concept of environment into one of the current educational reforms (STEM education) and teacher education. Ultimately, the issues and challenges related to EL are discussed through a detailed and comprehensive view, and practical solutions are presented in this thesis.

2.8. Key Message

Summary of Chapter 2
• In general, the purposes of two research fields (Research Field 1 and 2) including six studies (Studies 1 to 6) are summarized in figure 2.1. Field-1 has consecutive four studies, which are based on PISA data. There are two Delphi studies in the Field-2. In this process of dissertation (2 research fields including 6 studies), firstly the four studies are designed as quantitative research. After the quantitative studies, Delphi studies are carried out which include both qualitative and quantitative studies respectively. • Pragmatic Paradigm is adopted as philosophy. Sequential mixed method is used as a research design.
Issues
• Governments should consider the importance of EL in their own education systems and reform the education system for a more sustainable future. • It should be demonstrated in national studies as well as international studies to evaluate the quality and contributions of these reforms in the education system. • Researchers should demonstrate the importance and benefits of involvement of EL in international assessments.

Challenges

- When the framework of PISA is examined, even though its scientific literacy tasks include items related to environmental issues, EL is not been evaluated directly.
- The need and importance of integration of the environment into new educational reforms (especially STEM education, which is being implemented in SE) and teacher education should be emerged to educate more qualified environmental literate individuals.

Chapter 3. Results

In this chapter, the results of 'large-scale assessment studies' and 'Delphi studies' are included.

3.1. Results of Large-Scale Assessment (PISA) Studies

This part contains the important results with the main graphic(s) or/and table(s) for each research questions related to large-scale assessments.

3.1.1. Results of Study-1: The determination of the factor that affects the environmental perceptions based on PISA Data

This section includes thesub-questions and the results with the main graphic(s) or/and table(s) related to study-1.

3.1.1.1. Which factors affect EL of 15-years old German students?

In the study-1, there seems to be a positive and meaningful relationship between EL and EO at a low level. Moreover, there is a positive correlation between the EL of students and EA, ER.

3.1.1.2. What is the relationship between EL and SEC of the students (such as type of books and number of musical instruments at home)?

This sub-chapter includes the analyses of the students' SEC. Parametric tests, ANOVA, and t-tests are used to evaluate the data derived from the analysis of quantitative data.

Table 3.1. The results of the t-test and ANOVA for EL and SEC

Type of Books	Answer	N	$\bar{X}$	Sd	Df	t	ρ	η^2
Classic Literature	Yes	2,363	2.59	.27	5,500	3.86	.00	0,03
	No	3,139	2.56	.29				
Poetry	Yes	2,952	2.58	.28	5,554	2.06	.04	0,02
	No	2,604	2.56	.29				
Books on Art, Music or Design	Yes	2,928	2.59	.28	5,544	3.31	.00	0,03
	No	2,618	2.56	.28				
Books to help with school work	Yes	4,943	2.58	.28	5,621	1.35	.18	0,02
	No	680	2.56	.28				
Number of books at home	0-25	1,326	2.53	.31	5,673	5.55	.00	0,18
	More than 25	4,349	2.58	.27				
Type of SEC	**Answer**	**N**	$\bar{X}$	**Sig. Dif.**	**Df**	**F**	ρ	η^2
Musical Instruments	None (a)	1,725	2.56	d-a, d-b	3	7.43	.00	0,06
	1 (b)	1,379	2.56		5,669			
	2 (c)	1,050	2.58		5,672			
	3 and more (d)	1,519	2.60					

When the analyses of the students' socio-economic characteristics (SEC) are examined, there seems a significant relationship between both classic literature and books on art, music, or design that students have at home and EL. However, there seems no significant relationship between books of poetry and books to help with school work that students have at home and EL. Those who have these types of books at home have a higher average EL than those who does not. There seems a meaningful relationship between EL and a number of musical instruments at home. According to the results, the EL of students who have three or more musical instruments is more positive than those who have only a single musical instrument and those who have none. In addition, there seems a meaningful relationship between EL and SEC. Students' SEC seemed to affect their EL. Thus, it can be concluded that as the SEC increases, EL increases. These results show that SEC has a large effect on the EL.

3.1.1.3. What is the relationship between the EL and TC such as explanations, individualized help and the structure of lessons?

This sub-chapter includes analyses of the TC. ANOVA is used to evaluate the data derived from the analysis of quantitative data.

Table 3.2.a. The results of the ANOVA for EL and TC

Type of TC	Answer	N	$\bar{X}$	Source of Variance	Df	Mean square	F	ρ	Sig. dif.	η^2
Adapting Lessons	Never or almost never (a)	795	2.55	Between groups	3	.75	7.18	.00	d-a, d-b, c-a, c-b	0,07
	Some lessons (b)	1,548	2.55	With-in group	4,120	.11				
	Many lessons (c)	1,175	2.59	Total	4,123					
	Every lesson or almost every lesson (d)	606	2.61							
Individual Help	Never or almost never (a)	1,106	2.57	Between groups	3	.53	5.08	.00	d-a, d-b	0,06
	Some lessons (b)	1,603	2.55	With-in group	4,091	.11				
	Many lessons (c)	986	2.58	Total	4,094					
	Every lesson or almost every lesson (d)	400	2.62							
Explana-tions of Scientific Ideas	Never or almost never (a)	550	2.52	Between groups	3	1.10	10.91	.00	d-a, d-b, c-a, c-b	0,09
	Some lessons (b)	1,573	2.56	With-in group	4,227	.100				
	Many lessons (c)	1,373	2.59	Total	4,230					
	Every lesson or almost every lesson (d)	735	2.60							

When the analyses of the students' teaching characteristics (TC) are examined, there seems a meaningful relationship between EL and teachers' frequency of adapting the lesson to class needs and knowledge. According to the results, students' EL is higher for students whose teachers adapt lessons to their needs in every lesson or almost every lesson by the teacher and lower for those whose lessons are adapted sometimes or never or almost never. Additionally, there seems a meaningful relationship between EL and the frequency of teachers providing individual help when students have difficulties. According to the results, the EL of the students who are provided with individual help in every lesson or almost every lesson (was higher positive than that of those who did so sometimes, or never or almost never). Furthermore, there seems a meaningful significant relationship between EL and frequency of teacher's explanations of scientific ideas. According to the results, the EL of the students whose teachers explain scientific ideas in every lesson or almost every lesson is higher than those who do so sometimes or never or almost never.

Table 3.2.b. The results of the ANOVA for EL and TC

Type of TC	Answer	N	$\bar{X}$	Source of Variance	df	Mean square	F	p	Sig. dif.	η^2
Teachers' Conti-nuing to Lecture	Never or hardly ever (a)	607	2.58	Between groups	3	.095	.98	**.40**	-	0,02
	Some lessons (b)	1,134	2.57	With-in group	4,447	.097				
	Most lessons (c)	1,360	2.56	Total	4,450					
	Every lesson or almost every lesson (d)	1,350	2.58							
Changing the Structure of Lessons	Never or almost never (a)	1,337	2.56	Between groups	3	.498	4.72	.00	d-b	0,06
	Some lessons (b)	1,433	2.55	With-in group	4,078	.105				
	Many lessons (c)	925	2.59	Total	4,081					
	Every lesson or almost every lesson (d)	387	2.61							

When the analyses of the students' teaching characteristics (TC) are examined, there seems no significant relationship between EL and frequency of teachers continuing to lecture. Accordingly, it can be said that as the frequency of teachers continuing to lecture increases, EL does not increase. However, there seems a meaningful relationship between EL and frequency of teacher changing the structure of lessons to suit class needs. According to the results, the EL of the students whose teachers change the structure of lessons to suit class needs every lesson or almost every lesson was higher than that of those whose teachers do so sometimes.

3.1.2. Results of Study-2: Comparison of the change in environmental literacy (2006-2015) in Germany

This chapter includes sub-questions and results with the main graphic(s) or/and table(s) related to study-2.

3.1.2.1. What factors influence EL?

As seen in Section 2.1.2, in the study-2, it can be seen that among the factors related to the "ER", the factor of "acid rain", has the highest factor value in 2006. However, in 2015 the highest factor is "food items". As seen in figure 3.1., the factor, "health issue", has the lowest factor value in 2006 and 2015.

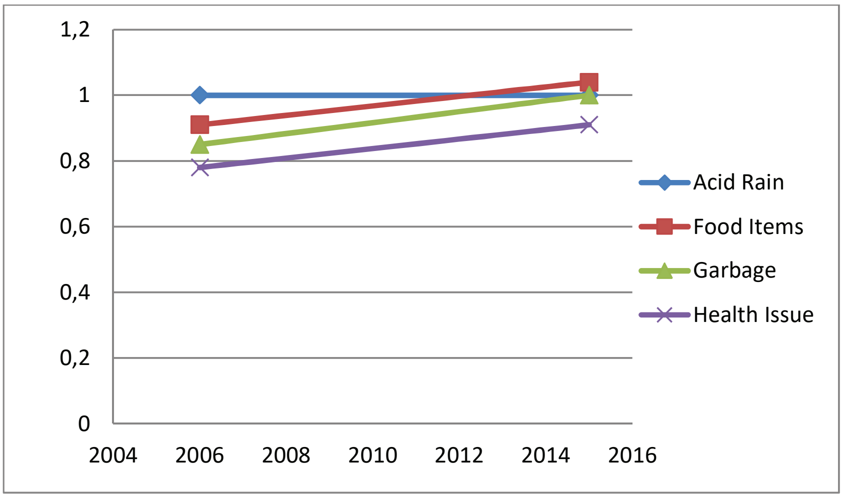


Figure 3.1. Change in ER based on PISA 2006 data and PISA 2015 data

On the other hand, it can be seen that among the factors related to the "EA" of the German students, the factor of “greenhouse gases” has the highest factor value in 2006 and 2015. In addition, as seen in figure 3.2, the "use of genetically modified organisms (GMO)" has the lowest factor value in both 2006 and 2015.

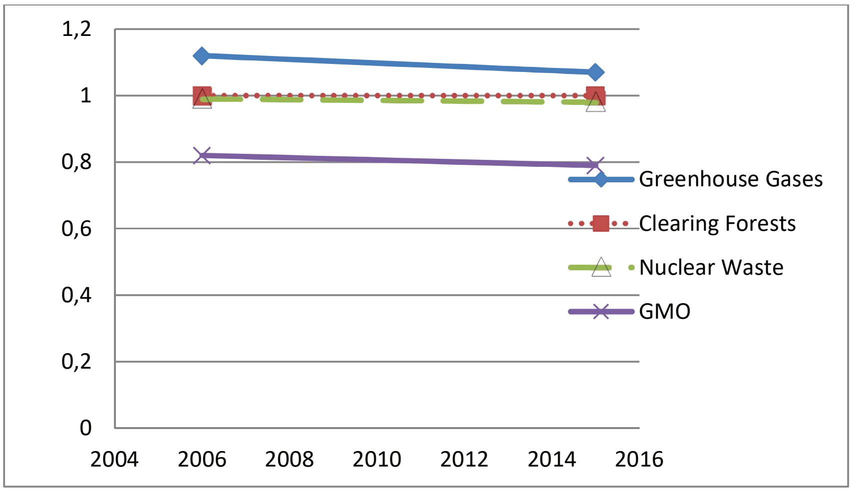


Figure 3.2. Change in EA based on PISA 2006 and PISA 2015 data

3.1.2.2. In what way do the EL factors (development of environmental behaviour, environmental awareness and environmental responsibility) change from 2006 and 2015?

According to PISA 2006 and 2015 data, the majority of the students indicate that ‘they can describe the role of antibiotics in the treatment of disease’ and ‘they can predict how changes to environment will affect the survival of certain species’ easily on their own. However, approximately 20 % of the German students point out that they could not recognize the science question underlining a newspaper report on a health issue on their own. Moreover, more than half of the students mention that they struggle to understand the health issue. An increase is seen in the percentage of students who stated they could not identify the better of two explanations for the formation of acid rain, from 2006 (11.8%) to 2015 (17%). Conversely, the majority of the German students point out that they have information about the consequences of clearing forests for other land use. More than 60% of the German students indicate that they have knowledge about nuclear waste. On the other hand, more than 60% of the German students believe that they do not have sufficient knowledge about the use of GMO.

3.1.2.3. How does the change in the influence of students' attitudes towards science (such as enjoyment of science, interest in science) impact EL from 2006 to 2015?

This section includes analyses of the attitudes towards science. ANOVA is used to evaluate the data derived from the analysis of quantitative data.

Tablo 3.3. The results of ANOVA, as related to EL and having fun when learning science

	View	N	$\bar{X}$	Source of Variance	Sd	Mean Square	F	p	Sig dif
PISA 2006	Strongly agree(a)	1145	1.87	Between groups	3	1.90	24.82	.00	a-b, a-c, a-d
	Agree(b)	1850	2.15	With-in group	4702	.08			
	Disagree(c)	1273	2.41	Total	4705				
	Strongly disagree(d)	438	2.73						
PISA 2015	Strongly agree(a)	899	2.57	Between groups	3	.176	1.93	.12	-
	Agree(b)	1499	2.58	With-in group	4058	.091			
	Disagree(c)	1044	2.60	Total	4061				
	Strongly disagree(d)	620	2.57						

The results of the study-2 show that there is a meaningful difference in terms of EL averages and having fun when learning science topics in 2006, whereas in 2015, there is no meaningful difference. According to the results, the EL of the students who strongly disagree with the fun of learning science is stronger than that of the other students in 2006. Moreover, while there is a significant increase from 2006 to 2015 in terms of the average of the students who strongly agree with the fun of learning science, there is a decrease in terms of the average of the students who strongly disagree with the fun of learning science.

Tablo 3.4. The results of ANOVA as related to EL and the interest in learning about science

Attitude		View	N	x̄	Source of Variance	sd	Mean Square	F	p	Sig Dif
interest in learning about science	2006	Strongly agree(a)	1015	2.51	Between groups	3	2.45	32.03	.00	a-c, a-d
		Agree(b)	1799	2.53	With-in group	4699	.08			
		Disagree(c)	1331	2.57	Total	4702				
		Strongly disagree(d)	558	2.64						
	2015	Strongly agree(a)	794	2.56	Between groups	3	.379	4.13	.006	-
		Agree(b)	1492	2.57	With-in group	4023	.092			
		Disagree(c)	1032	2.60	Total	4026				
		Strongly disagree(d)	709	2.60						
like reading science	2006	Strongly agree(a)	1421	2.51	Between groups	3	2.34	30.52	.00	a-b, a-c, a-d
		Agree(b)	585	2.52	With-in group	4704	.08			
		Disagree(c)	1921	2.55	Total	4707				
		Strongly disagree(d)	781	2.62						
	2015	Strongly agree(a)	518	2.55	Between groups	3	.787	8.67	.00	d-a, d-b, d-c
		Agree(b)	1128	2.57	With-in group	4031	.09			
		Disagree(c)	1453	2.58	Total	4034				
		Strongly disagree(d)	936	2.62						

The study-2 also shows that there is a meaningful difference in terms of EL averages and interest in learning about science between 2006 and 2015. According to the results, the EL of the students who strongly disagree with interest in learning about science is stronger than that of the other students. However, by 2015, the averages of those who strongly disagree with the interest in learning science decreased, while the averages of those who strongly agree with the interest increased. On the other hand, there is a meaningful difference in terms of EL averages and like reading science between 2006 and 2015. According to the results, the EL of the students who strongly disagree with like reading science is stronger than the EL of the other students.

3.1.2.4. What changes occur from 2006 to 2015 in the influence of teaching methods for lessons on EL?

The results of ANOVA, as related to EL and teacher's teaching methods are obtained. The responses are shown in Table 3.5.

Table 3.5. The results of ANOVA as related to EL and teacher's explanation about how idea can be applied

	View	N	x̄	Source of variance	Sd	Mean Square	F	p	Sig Dif
2006	All lessons (a)	792	2.44	Between groups	3	8.67	116.25	.00	a-b, a-c, a-d
	Most Lessons(b)	1797	2.52	With-in group	4483	.08			
	Some lessons (c)	1463	2.60	Total	4486				
	Hardly ever (d)	435	2.71						
2015	All lessons (a)	749	2.43	Between groups	3	12.73	160.71	.00	a-b, a-c, a-d
	Most Lessons(b)	1720	2.54	With-in group	4387	.08			
	Some lessons (c)	1471	2.65	Total	4390				
	Hardly ever (d)	451	2.74						

When the changes in the teaching characteristics are examined in 2006 and 2015, there is a meaningful difference in terms of EL averages and teacher's explanation about how idea can be applied. According to the results, when students are never or hardly ever informed by the teachers in the science lessons, the EL average of the students is stronger than that of the other students. From 2006 to 2015, the literacy average increase when the teacher never or hardly ever offers explanations during their science lessons.

Table 3.6. The results of ANOVA, as related to EL and teacher's provision of an explanation of relation of science concepts to our life

	View	N	x̄	Source of Variance	Sd	Mean Square	F	p	Sig Dif
2006	All lessons (a)	417	2.40	Between groups	3	8.81	118.49	.00	a-b, a-c, a-d
	Most Lessons(b)	1296	2.49	With-in group	4456	.074			
	Some lessons (c)	1972	2.57	Total	4459				
	Hardly ever (d)	775	2.67						
2015	All lessons (a)	457	2.39	Between groups	3	12.10	153.16	.00	a-b, a-c, a-d
	Most Lessons(b)	1175	2.52	With-in group	4380	.08			
	Some lessons (c)	1745	2.61	Total	4383				
	Hardly ever (d)	1007	2.69						

There is a meaningful difference in terms of EL averages and teacher explaining the relation of science concepts to our life. According to the results, when students are never or hardly ever informed about the relevance of science concepts to our lives by teachers in the science lessons, the EL average of the students is stronger than that of the other students. The EL average is found to increase when the teacher never or hardly ever provides explanations about the relevance of science concepts to our lives during their science lessons.

3.1.3. Results of Study-3: The determination of the dimensions that influence the environmental literacy

This chapter includes sub-questions and results with the main graphic(s) or/and table(s) related to study-3. The sub-questions are:

- What are the main factors influencing the environmental literacy of the students in the age group of fifteen in Singapore, Estonia and Germany?
- How is the similarity between countries considering whether they are statistically significant or not?
- How much of the explained variance of the students' perceptions of environmental literacy averages is explained by the main factors covered in this research? How are the rates of disclosure compared to the countries?

In the study-3 the main factors affecting the EL are compared in Germany, Singapore and Estonia. It is found that there is a meaningful relationship between total variance of 14 predictive variables and EL of German students (as seen in figure 3.3.). These variables clarified for approximately the 21% of the total variance in EL, the dependent variable. In Germany, while the main determinants influencing EL positively are "extra-curricular activities" and "teacher's teaching skills"; the "teacher's disposition to teaching" determinant is the most negative determinant. "Extra-curricular activities" are the predictor variables that provide the highest contribution to the regression equation and the explanation rate is 10%.

On the other hand, there is a meaningful relationship between total variance of 14 predictive variables and EL of Singaporean students. These variables clarified for approximately the 21% of the total variance in EL, a dependent variable. Determinants that affect EL positively in Singaporean students are "extra-curricular activities", "teacher's teaching skills" and "attitude towards school". However, the most negative determinants are the "teacher's disposition to teaching", "teacher's feedback for academic development of student" and "interest in science content knowledge". The "extra-curricular activities" that provide the highest contribution to the regression equation and the explanatory rate is 13%.

In other respects, there is a meaningful relationship between total variance of 14 predictive variables and EL of Estonian students. These variables clarified for approximately the 16 % of the total variance in EL, a dependent variable. One of the main determinants that affect EL positively in Estonian students is "extra-curricular activities" and the other one is "teacher's teaching skills". "Teacher feedback for academic development of student" is the most important negative determinant. "Extra-curricular activities" are the predictor variables that provide the highest contribution to the regression equation and the explanation rate is 10%.

Feature	Germany	Singapore	Estonia
Total variance in EL	21%	21%	16 %
Most positive determinant	Extra-curricular activities	Extra-curricular activities	Extra-curricular activities
Second important positive determinant	Teacher's teaching skills	Teacher's teaching skills	Teacher's teaching skills
Most negative determinant	Teacher's disposition to teaching	Teacher's disposition to teaching	Teacher feedback for academic development of student
Second important negative determinant	Teacher feedback for academic development of student	Interest in science content knowledge and Teacher feedback for academic development of student	Teacher's disposition to teaching

Figure 3.3. Summary Results of Study-3

3.1.4. Results of Study-4: The determination of the effects of environmental perceptions on science literacy

This chapter includes sub-questions and results with the main graphic(s) or/and table(s) related to study-4.

3.1.4.1. What are the dimensions (effects of family, teacher, student, and teaching) influencing the Environmental Literacy (EL) of the German students?

Table 3.7. Regression Analysis on the main dimensions on the EL

Determinant	B	Std. Er.	Beta	T	P	Zero-Order	Partial
Constant	2,982	,102	-	29,372	,000	-	-
Effect of Family	-,065	,019	-,07	-3,383	,000	-,048	-,070
Effect of Teacher	-,199	,024	-,17	-8,295	,000	-,191	-,169
Effect of Oneself	-,102	,023	-,09	-4,523	,000	-,149	-,093
Effect of Teaching	,127	,016	,16	7,916	,001	,176	,162

$R = 0.28$, $R^2 = 0.08$, $F_{(4,2329)} = 48,84$, $p < .01$

In the large-scale assessment studies, study-4 revealed that there is a meaningful relationship between total variance of four predictive variables and EL. These variables clarified for approximately the 8% of the total variance in EL, the dependent variable. The main dimension negatively influencing EL is "teacher"; the "teaching" is the most positive dimension.

3.1.4.2. What are the environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) influencing the Science Literacy of the German students?

Table 3.8. Regression Analysis on the effect of environmental perceptions on SL

Determinant	B	Std. Er.	Beta	t	P	Zero-Order	Partial
Constant	415,665	13,829	-	30,058	,000	-	-
Environmental Awareness	51,630	2,859	,347	18,061	,000	,440	,326
Environmental Optimism	12,778	3,580	,061	3,569	,000	,106	,068
Environmental Responsibility	-26,120	2,673	,186	-9,773	,000	-,342	-,184
R= 0.47, R^2 = 0.22, $F_{(3,2729)}$ = 261,57, $p < .01$							

It is found that there is a meaningful relationship between total variance of 3 predictive variables and SL. These variables clarified for approximately the 22% of the total variance in SL, the dependent variable. The main factors positively influencing SL are "environmental awareness" and “environmental optimism”; the "environmental responsibility" is the negative affect.

In summary, the first research field demonstrates that EL can be assessed through large-scale assessment studies based on PISA. Additonally PISA is seen as an opportunity to add universal value to EL. However, the obtained results show that the definition and framework of environmental literacy has to be revised in order to develop EL. Therefore, in the second research field based on DELPHI studies, experts' opinions are consulted to produce effective solutions for revising the framework of EL in science curricula, textbooks, and teacher educational system.

3.2. Key Message

Issues

- There is a significant relationship between both classic literature and books on art, music, or design that students have at home and EL.
- There is a meaningful relationship between EL and number of musical instruments at home.
- There is a meaningful relationship between EL and SEC.
- There is a relationship between the EL and TC.
- The majority of the students indicate that 'they can describe the role of antibiotics in the treatment of disease' and 'they can predict how changes to an environment will affect the survival of certain species' easily on their own in both 2006 and 2015.
- More than 60% of the German students indicate that they have knowledge about nuclear waste.
- "Extra-curricular activities" determinant is the most positive determinant influencing EL in Germany, Estonia and Singapore.
- The main factors positively influencing SL are "environmental awareness" and "environmental optimism".

Challenges

- There is no significant relationship between books to help with school work that students have at home and EL.
- Approximately 20 % of the German students point out that they could not recognize on their own the science question underlining a newspaper report on a health issue. Moreover, more than half of the students mention that they struggled to understand the health issue.
- More than 60% of the German students believe that they do not have sufficient knowledge about the use of GMO.
- "Teacher's disposition to teaching" is the common negative determinant influencing EL in Germany, Estonia and Singapore.
- "Environmental responsibility" effect on SL in Germany negatively.

3.3. Results of DELPHI Studies

This chapter contains results with the main graphic(s) or/and table(s) for each research questions related to DELPHI studies.

3.3.1. Results of Study-5: Reaching consensus on this framework of EL in accordance with expert opinions.

This chapter includes sub-questions and results with the main graphic(s) or/and table(s) related to study-5.

3.3.1.1. The identification of experts' views concerning environmental literacy (1st Round Results of DELPHI Study)

In this field, firstly, the Delphi results related to framework of EL, which are obtained from first round are included. Some questions were asked to determine the experts' views regarding the concept of 'EL'. In this study, the abbreviations (E) for experts and (N) for number of experts' views will be used.

According to expert's views on definition, sub-dimensions and competencies of EL, the majority of experts (N = between 11 and 17) have perceived that the definition of EL includes 'intention to act and environmental responsible behavior', 'knowledge and understanding of environmental issues', 'attitudes and concern towards the environment', and 'moral and ethics towards the environment'. Examples are:

> *"It requires an individual to understand the relationship between the environment and human life. (E5)"*

> *"EL is that to be sensitive to the environment, and environmental issues. Furthermore, EL is having knowledge, understanding, and skills to protect the environment…On the other hand, it is mainly a cultural issue. (E10)"*

The majority (N=9) of experts report that the sub-dimensions of EL include 'environmentally friendly behaviors' and 'environmental attitudes'. For instance:

"…Understanding and feeling that one's actions make a difference. Believing in the importance of individual awareness of the environmental issues/problems. So, take individual and collective action to produces a positive change for the environment. (E 12)"

More than half of the experts believe that competencies of environmental literate individuals include 'intention to action to protect the environment', 'knowledge and understanding about environment issues', 'motivation towards the environment' and 'positive behavior towards the environment'. For example;

"They should not throw garbage into the environment, they should do a necessity of sustainable society: for example, reduce the release of gases such as CFC, HCFC, HBCF, use public transport, pay attention to the carbon footprint. (E2)"

According to experts who are responsible for the training of qualified environmental literate individuals, the majority of experts (N = between 8 and 13) have perceived that family, teachers and individual (him/herself) that are responsible for the development of environmentally literate individuals. For example;

"Family, teachers and employees who work at the school. (E8)"

"Family, teachers, individuals … are responsible for the promotion of development of a qualified environmental literate individual. (E10)"

On the other hand, institutions/social groups especially school, citizen associations, public media are responsible for the development of environmentally literate individuals. For instance;

> *"…Formal educational institutions, ministry of education, universities, policy makers ... (E2)"*

> *"…Printed and visual media, and municipalities. (E15)"*

According to expert's views on what to do to support the development of qualified EL, the experts (N = between 5 and 7) having perceived that 'teacher should gain intention to act and show environmentally friendly behavior', 'governments should support individuals to learn about environmental issues via public media' and 'non-government organizations should support individuals to take part in social, civil, and/or societal initiatives' for enhancing the development of environmentally literate individuals. For example;

> *"Firstly, positive role models should be developed in family, media and school. … It should be encouraged to take part in civil society organizations. (E4)"*

> *"Student should learn to be sensitive to the environment in the family environment. Students should participate in social responsibility projects in educational institutions. (E5)"*

> *"The importance of recycling, energy-saving, protecting environment should be taught from young ages in families, schools and societies. This culture should be*

adopted. Actually, TV programs also very powerful in cultural change. Therefore, TV series should be prepared. ... (E10)"

According to expert's views on topics that should be included in the curriculum and textbooks for the development of EL, the majority of experts (N = between 8 and 13 having perceived that 'nature of environmental concepts', 'examples of environmental problems', 'sustainability, social perspectives' should be included in the curriculum and textbooks for the development of EL. For example;

"Natural resources and its use (for economic purposes), behavior and attitudes that consider environmental use, modernization and post-modernization processes (in economic, demographic and social domains) and the (mis)use of natural resources, alternative models and proposals of living in society that foster the sensitive use of natural resources. (E7)"

"Ecosystems dynamics and interactions; biodiversity; ...; efficient use the natural resources: energy, water, air, soil and so on; population growth ... sustainable consumption; ... environmental changes and impacts on the lives; environmental problems and health; relationship between social, cultural and political systems and environmental issues… (E12)"

"Climate, environment, nature, food need, living love, natural energy sources and precaution. (E17)"

"Global and regional effects of environmental problems, examples of past environmental problems, environmental problems waiting for us in the future. (E20)."

According to expert's views regarding teaching methods and extra-curriculum activities for the development of EL, the experts having perceived that teaching methods especially project-based learning, problem-based learning, different discussion methods and collaborative learning and extra-curriculum activities, especially visit field trips/ excursions/ botanic garden and read a book/ newspaper about the environment are crucial for the development of EL. For example;

"Cooperative learning method, problem solving method, project-based learning method, case study. (E11)"

"Theoretical lessons should be given in order to learn the concepts. As a practical course, social responsibility project should be realized. In this regard, project competitions must be held by lectures supported by video presentations. (E8)"

"Lectures supported by video presentations, visit environmental websites. Environmental observations should be provided on site with nature trips. (E18)"

3.3.1.2. Reaching consensus on this framework of EL (2nd and 3rd Round Results of DELPHI Study)

In this section, the Delphi results (study-5), which are obtained from second and third rounds are included (as seen in Section 2.2.1). The results obtained at the end of the first round were used in both the second and third rounds. Each question represents each theme and each item represents each code. According to the results of the second step Delphi, there is no consensus on 17 of 81 items. Therefore, the third step of the Delphi study is necessary. The third step Delphi study improved to a lack of consensus on 12 of 81 items.

3.3.1.3. How do experts define environmental literacy?

Table 3.9. Components of the definition and sub-dimensions of environmental literacy

	Item	Round	$\bar{x}$	Sd	Responses % 5-7	4	1-3	Cons
Components of the definition of EL	Knowledge and understanding of environmental issues	**2.R.**	6.18	1.24	95.5	-	4.5	**Yes**
		3.R.	6.58	0.72	96.8	3.2	-	**Yes**
	Attitudes and concern towards the environment	**2.R.**	6.30	1.13	93.2	-	6.8	**Yes**
		3.R.	6.45	1.18	96.8	-	3.2	**Yes**
	Morals and ethics towards the environment	**2.R.**	6.33	1.23	83.7	9.3	7.0	**Yes**
		3.R.	6.55	0.85	96.8	-	3.2	**Yes**
	Intention to act with environmentally responsible behavior	**2.R.**	6.26	1.12	95.3	-	4.7	**Yes**
		3.R.	6.53	0.82	96.7	-	3.3	**Yes**
	** Improved skills to evaluate data, draw conclusions, and form opinions*	**2.R.**	-	-	-	-	-	**-**
		3.R.	6.11	1.20	84.2	10.5	5.3	**Yes**
	Interrelationship of knowledge, understanding, attitude, morals and ethics, and intentions and behaviors towards the environment	**2.R.**	5.80	1.61	81.8	9.1	9.1	**No**
		3.R.	6.03	1.49	80.6	9.7	9.7	**No**
Sub-dimensions of EL	Knowledge and understanding about environmental issues	**2.R.**	6.23	0.74	97.6	2.4	-	**Yes**
		3.R.	6.16	1.21	87	6.5	6.5	**Yes**
	"*legislation about environment*" should be added to the above item *	**2.R.**	-	-	-	-	-	**-**
		3.R.	5.40	1.77	73.4	13.3	13.3	**No**
	Environmental attitudes	**2.R.**	6.37	0.87	95.3	4.7	-	**Yes**
		3.R.	6.48	0.77	96.8	3.2	-	**Yes**
	Environmental motivation	**2.R.**	6.23	1.00	90.7	7.0	2.3	**Yes**
		3.R.	6.48	0.85	96.8	-	3.2	**Yes**
	Morals and ethics related to the environment	**2.R.**	6.37	0.85	95.3	4.7	-	**Yes**
		3.R.	6.55	0.62	100	-	-	**Yes**
	Intention to act in an environmentally-friendly manner	**2.R.**	6.42	0.76	97.7	2.3	-	**Yes**
		3.R.	6.55	0.81	96.8	3.2	-	**Yes**
	Environmentally-friendly behaviors	**2.R.**	6.55	0.63	100	-	-	**Yes**
		3.R.	6.74	0.45	100	-	-	**Yes**
	Sustainability	**2.R.**	6.48	0.85	95.5	4.5	-	**Yes**
		3.R.	6.77	0.56	100	-	-	**Yes**

In the light of expert opinions, the concepts that need to be included in the definition of EL are "knowledge and understanding of environmental issues", "attitudes and concern towards the environment", "morals and ethics towards the environment", and "intent to act with environmentally responsible behavior". Moreover, at the end of third round, "promotion of skills to evaluate data, draw conclusions, and form opinions" was added to the definition. This study expands on this definition and shows that it is necessary to include concepts of morals and ethics towards the environment; knowledge, understanding, attitude, morals and ethics, and intention and behavior towards the environment; and development of skills to evaluate data, draw conclusions, and form personal opinions in the definition of EL. Additionally, the sub-dimensions of EL are knowledge and understanding about environmental issues, environmental attitudes, environmental motivation, morals and ethics related to the environment, intention to act in an environmentally-friendly manner, environmentally-friendly behaviors, and sustainability.

3.3.1.4. What are the competencies of the environmentally literate individual?

Table 3.10. Competencies of environmental literacy

Item	Round	$\overline{x}$	Sd	Responses %			Cons
				5-7	4	1-3	
Knowledge and understanding about environment issues	**2.R.**	6.50	0.75	97.5	2.5	-	**Yes**
	3.R.	6.68	0.70	96.8	3.2	-	**Yes**
Responsibility towards the environment	**2.R.**	6.54	0.78	97.6	2.4	-	**Yes**
	3.R.	6.65	0.71	100	-	-	**Yes**
Awareness towards environmental issues	**2.R.**	6.56	0.67	100	-	-	**Yes**
	3.R.	6.61	0.62	100	-	-	**Yes**
Motivation towards the environment	**2.R.**	6.42	0.77	97.6	2.4	-	**Yes**
	3.R.	6.49	0.81	96.8	3.2	-	**Yes**
Morals and ethics towards environmental issues	**2.R.**	6.46	0.81	97.6	2.4	-	**Yes**
	3.R.	6.58	0.89	96.8	-	3.2	**Yes**
Social engagement related to the environment	**2.R.**	6.12	1.05	95.2	2.4	2.4	**Yes**
	3.R.	6.36	1.08	96.8	-	3.2	**Yes**
Intention to act to protect the environment	**2.R.**	6.49	0.81	97.6	-	2.4	**Yes**
	3.R.	6.65	0.88	96.8	-	3.2	**Yes**
Positive behavior towards the environment	**2.R.**	6.66	0.66	97.6	2.4	-	**Yes**
	3.R.	6.87	0.43	100	-	-	**Yes**
Sustainable knowledge about the environment	**2.R.**	6.44	0.81	95.1	4.9	-	**Yes**
	3.R.	6.74	0.68	96.8	3.2	-	**Yes**
Concrete sustainable activities towards the environment	**2.R.**	6.07	1.03	90.2	9.8	-	**No**
	3.R.	6.42	0.92	93.5	6.5	-	**Yes**

According to expert opinions, EL competencies that come to the forefront are “knowledge and understanding about environment issues”, “responsibility towards the environment”, “awareness of environmental issues”, “motivation towards the environment”, “morals and ethics regarding environmental issues”, “social engagement related to the environment”, “intention to act to protect the environment”, “positive behavior towards the environment”, “sustainable knowledge about the environment”, and “concrete sustainable activities towards the environment”.

3.3.1.5. Who is responsible for the development of qualified environmentally literate individuals? And what should be done?

At the end of Delphi study, there was a consensus on seven items (family, individual (himself/herself), educators, academics, scientists, teachers, and policy makers) who have responsibility for the development of qualified environmentally literate individuals. However, there was no consensus on the remaining six items (friends, employees who work at schools, country administrators, entrepreneurs, business people, and artists). The institutions/social groups and people that have a responsibility for the development of qualified environmentally literate individuals are varied. Experts believe that states and public media are responsible for the development of environmentally literate individuals; however, country administrators who manage the states and artists are not responsible.

In addition, people (business people and entrepreneurs) who work in industry are not responsible for the development of environmentally literate individuals, however, industries are responsible. The experts suggest that governments, families, teachers, non-governments organizations and public media should support the development of qualified EL. The families and teachers should inform children about environmental issues, promote the acquisition of morals and ethics towards the environment, and guide the development of positive attitudes towards the environment.

Moreover, teachers should support student development of intentions to act and show environmentally-friendly behavior. Governments should mandate the inclusion of more environmental topics and their practice in science curricula and support the environmental qualifications of their teachers. Non-government organizations should support participation in social, civil, and/or societal initiatives. Public media (newspapers, TV, etc.) should support learning about environmental issues.

3.3.1.6 Which concepts and contexts are included within the framework of environmental literacy? And which teaching methods and extra-curriculum activities are used for the development of environmental literacy?

Based on the core finding of the Delphi study, topics that should be included in the curriculum and textbooks for the development of environmental literacy are summarized in Table 3.11.

Table 3.11. Topics that should be included in the curriculum and textbooks for the development of environmental literacy

Item	Round	$\overline{x}$	sd	Responses %			Cons
				5-7	4	1-3	
Environmental perceptions (attitude, responsibilities, morals, etc.)	**2.R.**	6.46	0.93	91.9	8.1	-	**Yes**
	3.R.	6.55	0.85	93.5	6.5	-	**Yes**
Examples of environmentally-friendly behavior	**2.R.**	6.69	0.62	97.2	2.8	-	**Yes**
	3.R.	6.65	0.55	100	-	-	**Yes**
Nature of environmental concepts (ecosystems, ecology, natural resources, etc.)	**2.R.**	6.62	0.64	100	-	-	**Yes**
	3.R.	6.77	0.43	100	-	-	**Yes**
Examples of environmental problems (global warming, climate change, endangered species, etc.)	**2.R.**	6.76	0.55	100	-	-	**Yes**
	3.R.	6.90	0.40	100	-	-	**Yes**
Solutions for environmental problems (recycling, renewable energy, etc.)	**2.R.**	6.60	0.73	97.3	2.7	-	**Yes**
	3.R.	6.61	0.84	93.5	6.5	-	**Yes**
Sustainability (sustainable development and future, etc.)	**2.R.**	6.60	0.69	100	-	-	**Yes**
	3.R.	6.77	0.50	100	-	-	**Yes**
Social perspectives (interrelationship of environment, society, and technology, etc.)	**2.R.**	6.38	1.04	91.9	5.4	2.7	**Yes**
	3.R.	6.61	0.76	96.8	3.2	-	**Yes**

As seen in Table 3.11, at the end of Delphi study, there is a consensus on seven items regarding topics that should be included in the curricula and textbooks for the development of environmental literacy. When the second and third Delphi results are compared, the percentage of environmental perceptions, examples of environmentally-friendly behavior and social perspectives are increased. In addition, teachers should use various teaching methods in science classes for the development of EL such as out-of-school activities, collaborative learning, inquiry-based learning, project-based learning, experiments, context-based learning, problem-based learning, various discussion methods, and hands-on experiences. Moreover, for the development of EL, it is crucial to be aware of the importance of extra curriculum activities such as visiting web sites of environmental organizations, participating in environmental clubs, visiting science and art museums, and taking field trips.

Teaching methods	Extra-curriculum activities
• Project-based learning • Problem-based learning • Different discussion methods • Inquiry-based learning • Out-of-school activities • Hands-on experiences • Collaborative learning • Context-based learnin	• Visit web sites of environment organizations • Field trips and excursions • Participate in environment clubs and activities • Visit science and arts museums

Figure 3.4. Views regarding teaching methods and extra-curriculum activities for the development of environmental literacy

3.3.2. Results of Study-6: The determination of what teachers should do for their experiences and qualifications as environmental STEM literate individuals

The study-6 includes both qualitative and quantitative results. Table 3.12 presents the views on how teachers develop their experiences and qualifications as environmental STEM literate individuals.

Table 3.12. Views on how teachers develop their experiences and qualifications as environmental STEM literate individuals (Qual.)

Thema	Code	N
Responsibility of teachers as environmental literate individuals	To have content knowledge about environmental issues	3
	To have pedagogical competencies to teach about the environmental issues.	3
	To update their knowledge about environmental issues	2
	To apply the technology related to environment (nanotechnology and environmental technologies etc.)	1
	To follow the development of the environmental technologies	1
	To develop their competencies for teaching environmental topics.	1

According to Table 3.12, the majority of experts believe that 'teachers should have content knowledge about environmental issues and have pedagogical competencies to teach about the environmental issue'.

Table 3.13. How teachers should develop their experiences and qualifications as environmental STEM literate individuals

Item	Round	$\bar{x}$	sd	Responses % 5-7	4	1-3	Cons
Teachers should have content knowledge about environmental issues	**2.R.**	6.56	0.63	100	-	-	**Yes**
	3.R.	6.77	0.50	100	-	-	**Yes**
Teachers should constantly update their knowledge about environmental issues	**2.R.**	6.63	0.66	97.6	2.4	-	**Yes**
	3.R.	6.77	0.50	100	-	-	**Yes**
Teachers should follow the development of environmental technologies	**2.R.**	6.34	0.88	97.6	-	2.4	**Yes**
	3.R.	6.45	0.77	100	-	-	**Yes**
Teachers should apply technology related to the environment (nanotechnology, environmental technologies, etc.)	**2.R.**	6.12	1.15	91.8	4.9	4.9	**Yes**
	3.R.	6.13	1.01	90.0	10.0	-	**Yes**
Teachers should have pedagogical competencies to teach about environmental issues	**2.R.**	6.54	0.75	97.6	2.4	-	**Yes**
	3.R.	6.68	0.70	96.8	3.2	-	**Yes**
Teachers should consistently develop their competencies for teaching environmental topics	**2.R.**	6.61	0.63	100	-	-	**Yes**
	3.R.	6.71	0.59	100	-	-	**Yes**

As seen in Table 3.13, at the end of Delphi study, there is a consensus on six items about how teachers should develop their experiences and qualifications as environmental STEM literate individuals. When second and third Delphi results were compared, the percentage of 'teachers should constantly update their knowledge about environmental issues and follow the development of environmental technologies' increased, however, the percentage of 'teachers should apply technology related to the environment' decreased. They should follow the development of environmental technologies and application of other technology related to the environment (nanotechnology and environmental technologies, etc.). Teachers should develop pedagogical competencies to teach environmental issues and consistently develop their competencies for teaching environmental topics.

3.4. Key Message

- According to the results of the second step Delphi, there is no consensus on 17 of 81 items. Therefore, the third step of the Delphi study is necessary. The third step Delphi study improved to a lack of consensus on 12 of 81 items.
- In the light of expert opinions, the concepts that need to be included in the definition of EL are “knowledge and understanding of environmental issues”, “attitudes and concern towards the environment”, “morals and ethics towards the environment”, and “intent to act with environmentally responsible behavior”. Moreover, at the end of third round, “promotion of skills to evaluate data, draw conclusions, and form opinions” is added to the definition.
- At the end of Delphi study, there was a consensus on seven items (family, individual (himself/herself), educators, academics, scientists, teachers, and policy makers) who have responsibility for the development of qualified environmentally literate individuals. However, there was no consensus on the remaining six items (friends, employees who work at schools, country administrators, entrepreneurs, business people, and artists).
- Teachers should use various teaching methods in science classes for development of EL such as out-of-school activities, collaborative learning, inquiry-based learning, project-based learning, experiments, context-based learning, problem-based learning, varied discussion methods, and hands-on experiences.
- For the development of EL, it is crucial to be aware of the importance of extra curriculum activities such as visiting web sites of environmental organizations, participating in environmental clubs, visiting science and art museums, and taking field trips.

- Teachers should follow the development of environmental technologies and application of other technology related to the environment (nanotechnology and environmental technologies, etc.).
- Teachers should develop pedagogical competencies to teach environmental issues and consistently develop their competencies for teaching environmental topics.

Chapter 4. Discussions and Conclusions

In this chapter, the findings of the large-scale assessment studies and Delphi studies will be discussed.

4.1. Discussions and Conclusions on Large-Scale Assessment (PISA) Studies

In the first part, based on the PISA data, the results concerning 'the factors affect EL of 15-years old German students', 'knowledge about environmental issues: change in the EL of German pupils from 2006 to 2015', 'the relationship between EL and SEC of the students', 'the main factors influencing the environmental literacy of the students' and 'what is the relationship between the EL and TC' will be discussed.

4.1.1. Which factors affect EL of 15-years old German students?

In the first research field, the basic framework for understanding EL in the light of the PISA 2015 data is revealed. EL is a measurement of an individual's knowledge about the interactions between people and their environments, environmental issues, and the various related to ecological issues (Burchett, 2015). There is a positive and meaningful relationship between EL and EO, EA and ER.

In the second research field, there was a positive relationship determined between EL and ER, DEB and EA. Otherwise it is stated, when sub-dimensions are positively supported, this might provide a positive contribution to the students' EL development. Furthermore, according to study-4 of large-scale assessment studies, environmental awareness and optimism have a positive effect on the science achievement; but environmental responsibility has a negative effect on it. Therefore, for improving students' both academic success and average of EL, environmental responsibility should be gained to the children through the educational system. In this way, individuals might prevent environmental degradation, solve environmental problems and act positive behavior towards the environment (Wenshun, Xiaohua, and Hualong, 2011).

4.1.2. Knowledge about environmental issues: change in the EL of German pupils from 2006 to 2015

As seen in Study-2, according to 2006 and 2015 PISA data, the students constituting the study have more knowledge about "greenhouse gases" than about other items. More than half of the German students have knowledge on the "greenhouse gases", the "consequences of clearing forests for other land use", and "nuclear waste". In line with this finding, in the research conducted by Yurttas and Sulun (2010), second-grade primary school students specify global warming, ozone layer depletion and acid rain to be the biggest environmental problems in the world. In another study with similar results, elementary students were shown to be mostly aware of the environmental problems stemming from environmental contamination, air pollution and waste materials (Demirbas and Pektas, 2011). To continue, in a study by Negev et al. (2010), it was reported that most of the twelfth-grade student participants indicate “solid waste”, or “air pollution”, to be major environmental issues. In general, studies have shown that students view “air pollution”, “global warning” and “greenhouse gases” as the most important environmental issues. People tend to have more knowledge about matters that have a concrete impact on their lives. Moreover, social media has helped to draw attention to global problems, including of course those related to environmental issues. The study by Incekara and Tuna (1991) give support to the role that social media plays in spreading environmental knowledge. They reported that secondary students tended to have sufficient information on issues such as air pollution, desertification and climate change. Similar results have been observed in research conducted on the environmental awareness of teacher candidates. In a study conducted by Artun, Uzunoz and Akbas (2009), teacher candidates point to global warming and air pollution as important environmental problems. Diken and Sert Cibik (2007) suggest that teacher candidates have cognitive and sensitive dimensions of environmental consciousness. However, these dimensions are not sufficient in terms of reflecting the environmental knowledge they have onto their behaviours (Diken and Sert Cibik, 2007; Kaya et al., 2009). This could be attributed to their lack of environmental awareness (Guven and Aydogdu, 2012; Ercengiz, et al., 2014). According to Kahyaoglu et al. (2008), environmental behaviour is influenced environmental knowledge and awareness. Therefore, teacher candidates, especially science teachers, should be supported to increase their level of environmental awareness, and they should be encouraged to translate their environmental awareness into environmentally responsible behaviour. For the sake of securing our future, it is crucial that students should be taught a high level of environmental awareness. In the present study, the German students had the lowest awareness of “use of GMO”. However, interestingly, more students in 2015 PISA data seemed to have never heard of this concept. When the opinions of the students are taken to determine their knowledge level on this subject, the German students report that they do not have sufficient knowledge about GMOs. Similarly, in a separate study, it is found that students have insufficient information and misleading concepts about greenhouse gases (Bahar and Aydin, 2002). These results are in line with those from Darcin et al. (1991), who report that the levels of knowledge elementary students have on the greenhouse effect are too low. In another study, biology teacher candidates had incorrect ideas about the greenhouse effect (Selvi and Yildiz, 2009). Regarding the subject of GMO, Gurbuzoglu Yalmanci (2016) reports that both high school students and teacher candidates have some misunderstandings about GMO. University students seemed to have insufficient knowledge about GMO (Temelli and Kurt, 2011). In a study conducted by Cankaya and Filik Iscen (2015), however, science teacher candidates had sufficient information about the meaning of the concept of GMO, although, they had incorrect knowledge about the production of GM crops, the use of GMO in their country, and their effects.

Despite the increase in the health coefficient from 2006 to 2015, it is nonetheless seen that health issues are still not given importance. In support of this finding, approximately 20% of the German students, in both 2006 and 2015, revealed that they are unable to recognize a health problem. Moreover, more than half of the students mention that they struggle to understand the health issue. Research shows that overuse of antibiotics poses a threat, not only to human health but also to the environment (Yesil Aski, 2013).

Individuals need to be taught greater awareness about health issues in order to create a healthier public in the future. In addition to the lack of understanding of health issues, it is also found that there is an increase in the percentage of the students who indicate that they were unable to explain acid rain. Therefore, “acid rain” and “health issues” should be emphasized in future science curricula.

4.1.3. What is the relationship between EL and SEC of the students?

The study-1 showed there is a significant relationship between EL and the number of musical instruments and books at home (SEC). Oral and McGivney (2013) mention that one of the factors thought to affect student achievement is having books at home. Other similar studies have found that books have positive effects on scientific literacy (Ozer and Anil, 2011; Kaya and Dogan, 2016) and mathematics literacy (Ozer and Anil, 2011). However, in the study-3 (comparative study), "socio-economic characteristics" determinant is not a meaningful determinant in EL in Germany and Singapore.

In addition, study-1 shows that there is a significant relationship between both “classic literature” and “books on art, music, or design” that students have at home and EL. On the other hand, this study highlights that there is no significant relationship between both “books of poetry” and “books to help with school work at home”. Furthermore, “classic literature” and “books on art, music, or design that students have at home” have greater positive effects on EL. Ozer and Anil (2011) claim that there is a relationship between scientific literacy and educational materials that students have at home, but there is no relationship between mathematics literacy and educational materials. Furthermore, as reported by Abdu-Raheem (2015), there is a relationship between the academic performance of students and the SEC of their families. This research also shows that there was a significant relationship between EL and SEC. A similar finding is mentioned by Erbas et al. (2012). Turkish students' responsibility toward the environment varies by SEC. In a similar vein, Lin and Shi (2014) mention that economic, social, and cultural status, internal student factors, seem to affect certain aspects of EL. This study finds that students' SEC affects their EL, and as SEC increases, EL increases. Studies have indicated that SEC has a significant effect (Hattie, 2003) and its importance for teaching (Lotz and Lipowsky, 2015). Lotz and Lipowssky (2015) in an updated study of Hattie's (2003) study finds the effect size between student achievement and SEC (such as family resources) was d = 0.52. Consequently, these results show that SEC is effective in both student achievement and EL.

4.1.4. What are the factors influencing the environmental literacy of the students?

It is seen in study-4 of large-scale assessments studies that social (students and their families) perspectives have a negatively effect on EL. For this reason, both the students and their families should be supported for the quality of the education. In the study-3, with the help of the "test anxiety of student" factor which is one of the student-derived factor, students are having a positive effect on EL. An anxiety at a certain level, can have a positive effect on students' EL. However, if the anxiety rises more, it can turn into a negative effect. Since, test anxiety causes a negative effect on academic achievement in different studies (Rana and Mahmood, 2010; Olatoye, 2009; Yildirim, 2000). "Attitude towards the science", the other student-generated factor, has a negative impact on EL of students in both Germany and Singapore in contrast, a positive impact on EL in Estonia. This effect is meaningful for German and Estonian students; but it does not seem to make sense for Singaporean students.

In her studies, Anil (2009, 2011) used PISA 2006 data to identify students' "attitudes toward science" as one of the most predictive variables of science achievement. Other studies (Akpınar et al., 2009; Ali, Iqbal and Akhtar, 2015) indicate that there is a meaningful and positive relationship between attitudes towards science and technology, and academic achievement. Besides, Criker (2006) found that there is a strong relationship between attitude towards science and achievement. Similar results have been obtained in studies conducted in different interdisciplinary fields. In one of these, it is seen that there is a relationship between the "attitude towards the course" and "mathematics success" (Savas, Tas and Duru, 2010).

One of the most common challenges in science education is how to motivate students and how to increase interest in science learning (Rannikmäe, Teppo and Holbrook, 2010). When countries have an effective solution to this question, it might be a positive effect on their academic achievement.

Another factor which is "attitude towards school" has a positive impact on the EL of students from all three countries. This effect has been achieved for Estonian and Singaporean students, but it is meaningless for German students. In Moè, et al. (2009), point out that the relationship between emotional motivation variables and academic achievement is the role of the attitude toward the arrow. Moreover, Verešová and Malá (2016) mention that 'the attitude toward school and learning' is an important predictor of achievement. Therefore, the more positive is 'the "attitude towards school" and "learning of students", the more positive is “academic achievement” at the end of the school year. Abu-Hilal (2000) reveals that attitudes toward school influence achievement, however, only indirectly.

In Sarier’s (2016) study, the most important factors affecting the academic success of students are found to be socio-economic status, self-efficacy and motivation. On the other hand, Farooq et al. (2011) found that socio-economic characteristics and parents’ education have a significant effect on students’ overall academic achievement. However, "educational level of parents" determinant is not the significant determinant for the EL in three countries.

4.1.5. What is the relationship between the EL and TC?

In the Study-4, based on PISA data, it is seen that the dimension that is related to the teacher has the most negatively effect on EL. On the other hand, the dimension of teaching has the positively effect on EL. The link between students and teachers is important for the attainment of educational goals (Nembhard, 2005). An important part of the responsibility for strengthening this bond belongs to teachers. For this reason, raising the educational standards of teachers, who are schools’ most important resource, is critical (OECD, 2009b). The instructional ability of the teacher has a powerful effect on achievement (Hattie, 2003). In particular, the teaching process should be supported to improve the quality of education. Thus, educators are exploring ways to create schools that improve the learning and performance of students in many parts of the world (Whole Schooling Research Project, 2000).

The character of a teacher is also significant for effective teaching practices in enriched learning environments (Pennock and Moyers, 2012). The study-1 results provide evidence that there is a significant relationship between teachers adapting lessons to their students' needs and knowledge, changing the structure of their lessons, providing individual help when students have difficulties and explaining science ideas in every lesson and EL. However, according to PISA 2006 and 2015 data, as seen in study-2), approximately 25% of the students reported that they never or hardly ever spent time in the laboratory doing practical experiments as part of their science lessons. Furthermore, more than half of the students noted that they never or hardly ever are allowed to design their own experiments in the science lessons. Moreover, while in 2006 PISA data, the students state that they are not able to express themselves enough in science classes, in 2015 PISA data, the students mention class discussions and their expectations regarding the planning of science lessons so as to allow for the discussion of different opinions. The students express their expectations that they would like their science lessons to be more student-centered. In other words, they want actively to participate in the process by taking responsibility in lessons. In fact, researchers have identified these characteristics as effective teacher skills. Concerning effective teachers, Sprague (2012: 3) states that "they can adapt or differentiate instruction for all students by using some basic problem-solving techniques that involve quickly identifying issues, generating alternative solutions, and trying one or two to see if they work".

On the other hand, the study-1 findings suggest that there was no meaningful relationship between teachers continuing to lecture in their science lessons and EL. The reason for this may be that students want a student-centered learning environment instead of a teacher-centered learning environment. In addition, various approaches can be used for student-centered learning, including case-based learning, project-based learning, and problem-based learning (Pederson and Liu, 2003). Unlike traditional teaching, these environments focus on meaning formation, inquiry, and authentic activity (Garrett, 2008). These environments acknowledge that each student can learn, research, and analyze current knowledge in a different way (Attard et al., 2010).

Ultimately, individual support given by teachers has a positive effect on EL. For this reason, teachers should create atmospheres in which students are supported. In another similar study, Becker and Luthar (2002) pointed out that teacher support is influential on achievement performance). According to Akiri (2013), quality teachers produce better performing students; however, the observed differences in students' performance are statistically not significant. Adapting all lessons to the needs of the students and changing the structure of lessons accordingly can help students to increase their EL. According to study-3, based on PISA data, when the teacher-derived factors are examined, "teacher's teaching skills" factor has a positive and significant effect in all three countries. However, "teacher's disposition to teach" has a significant negative impact. "Teacher's feedback for academic development of student" is found to be another teacher-driven factor that has a significant impact on EL in the negative direction in all three countries. Although lecturing does not affect EL, as seen in the first study based on PISA, "teachers' explanations of scientific ideas in science lessons" increase EL. According to study-2, however, when the teacher never or hardly ever provides explanations showing the relevance of science concepts to our lives or/and explanations about how a school science idea can be applied during a science lesson, the average rate of EL increases. While in 2006 PISA data, the students state that they are not able to express themselves enough in science classes, in 2015 PISA data, the students mention class discussions and their expectations regarding the planning of science lessons so as to allow for the discussion of different opinions. As a result, while teachers share their scientific ideas in science lessons with students, this sharing should not be directly informed the students about science concepts or how to apply them in our daily lives. In fact, it can be argued that teacher-centered education has a negative effect on EL. Therefore, student-centered lessons should be applied to provide more academic support for the improvement of EL skills. A student-centered approach also provides opportunities for students to increase their interest and attitude towards science. If these are increased, the students will have a chance to improve their literacy. Interest and positive attitude towards science, academic development support and EL are the concepts that affect each other.

In the light of selected determinants in comparative study, as seen in Study-3, "extra-curricular activities" that is associated with the curriculum that has the most significant positive impact on EL among all three countries' students. The determinant "extra-curricular activities" has the greatest positive impact on EL of German students. In a similar study, Adeyemo (2010) mentioned that out-of-school activities have an important effect on the students' physical success. However, Sayin and Gelbal (2014) found that participation in social activities was the least important factor in the success of students. In analysing PISA 2006 data, Yildirim's (2012) identified family characteristics as the most important factor of the educational qualities of Turkey.

Although PISA data shows the basic framework for understanding EL as a general assessment, it is very important to update and review environmental literacy for the next large-scale assessment. Delphi study, therefore, aims to reach a consensus of experts on a more comprehensive framework of EL by using the basic framework obtained from PISA data.

4.2. Discussions and Conclusions on Delphi Study

In this part, the questions including 'how do experts define environmental literacy?', 'what are the competencies of the environmentally literate individual?', 'which concepts and contexts are included in the framework of EL? And which teaching methods and extra-curriculum activities are used for the development of EL?' and 'who is responsible for the development of qualified environmentally literate individuals? And what should be done?' are discussed. It is also comprised the sub-questions related to studies.

4.2.1. How do experts define environmental literacy?

EL involves the ability to adapt to changes in environmental resources and systems, and their dynamics (Scholz, 2011). In general, EL is equipped with more than just knowledge about ecology; completely literate individuals combine knowledge with values, which leads to action (Morrone, Mancl & Carr, 2001). EL also is capable of individually and collectively making informed decisions concerning the environment, are willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment, and are actively engaged in social life (Hollweg, et al., 2011). In short, Ireland (2013: 6) expresses her opinion that EL comprises scientific, technological, political, economic, social and cultural principles and value systems, as well as the aesthetic, moral, ethical and spiritual understanding needed to create ethical, engaged entrepreneurial citizens in the light of literature review. As mentioned in previous sentence, it is easily seen that concept of EL is on continuous development. The framework of EL should be updated for enhancing the development of environmentally literate individuals. Experts' definitions of EL, as obtained from the first step Delphi study of study-5, are listed below;

- Intention to act and environmental responsible behavior,
- Knowledge and understanding of environmental issues,
- Attitudes and concern towards the environment,
- Moral and ethics towards the environment,
- Interrelationship of 'knowledge', 'understanding', 'attitude', 'moral and ethics' and 'intention and behavior' towards the environment,

According to the experts, derived from second and third round Delphi studies, the concepts "knowledge and understanding of environmental issues", "attitudes and concern towards the environment", "morals and ethics towards the environment", and "intent to act with environmentally responsible behavior" should be included in the definition of EL. Moreover, "promotion of skills to evaluate data, draw conclusions, and form opinions" should be added to the definition.

The current definition of EL includes common concepts such as the ability to perceive, interpret, and make informed decision about environmental issues, understand ecosystems, and be aware of the importance of natural phenomena (Roth, 1992; Minner and Klein, 2016; North Carolina Department of Environmental Quality, 2017). Moreover, EL has been defined by many researchers. One of the definitions was included communicates and applies major ecological concepts and principles, understands how man's activities influence the environment, identify and investigate environmental issues and alternative solutions, and assimilates environmental values needed for rational and responsible use of environmental resources (Subbarini, 1998). In other words, definition of EL covers the development of knowledge, attitudes, and skills necessary to make informed decisions concerning the relationships among natural and urban systems (DC EL Workgroup, 2012). This study expands on this definition and shows that it is necessary to include concepts of morals and ethics towards the environment; the interrelationship of knowledge, understanding, attitude, morals and ethics, and intention and behavior towards the environment; and development of skills to evaluate data, draw conclusions, and form personal opinions in the definition of EL.

4.2.1.1.Which sub-dimensions are included in EL?

According to the results of first round Delphi study, the following sub-dimensions of EL should be included;

- Environmentally friendly behaviors,
- Environmental attitudes,
- Knowledge and understanding about environmental issues,
- Moral and ethics related to the environment,
- Intention to act environmentally friendly,

- Environmental motivation,
- Sustainability.

The results of second and third round Delphi studies inform that the sub-dimensions of EL are “knowledge and understanding about environmental issues”, “environmental attitudes”, “environmental motivation”, “morals and ethics related to the environment”, “intention to act in an environmentally-friendly manner”, “environmentally-friendly behaviors”, and “sustainability”. The similar research has also shown (Loubser, Swanepoel and Chacko, 2001: 321) that the concepts related to EL are “basic understanding of the biosphere and an ecological perspective of nature and human beings”, “awareness of human interactions with the environment and interrelationships in an ecosystem”, “knowledge of environmental changes”, “understanding of the activities to meet basic human needs”, “awareness of renewable and non-renewable resources”, “knowledge of how to maintain environmental quality and quality of life”, “understanding about the ability to make choices” and “knowledge of decision making on environmental issues and environmental ethics”. The other similar study (Liu, Yeh, Liang, Fang and Tsai, 2015) highlights that EL assessment framework encompasses three main domains (cognitive, affective and behavioral). In brief, common sub-dimensions related to EL are “knowledge”, “attitudes”, “values”, “skills”, “responsibility”, and “active involvement” (UNESCO, 1977; Roth, 1992; Kaya and Elster, 2017). However, future EL research should include “morals and ethics”, “motivation”, and “sustainability”. Mohammed (2006) mentions that humans need values for protecting and enhancing their environment and the quality of -life.

4.2.2. What are the competencies of the environmentally literate individual?

The concept of competency has multiple meanings and it is not easy to express with precision in daily life (Post, Rannikmäe and Holbrook, 2011). Especially, EL is a concept integrating several competencies which encourage pro-ecological behavior (Bissinger and Bogner, 2017). In this dissertation, competencies of the environmentally literate individual are determined by experts. According to first round Delphi study, the competencies of environmental literate individuals have;

- Intention to action to protect the environment,
- Knowledge and understanding about environment issues,
- Motivation towards the environment,
- Positive behavior towards the environment,
- Moral and ethics towards environmental issues,
- Social engagement related to the environment,
- Responsibility towards the environment,
- Awareness towards environmental issues,
- Concrete sustainable activities towards the environment,
- Sustainable knowledge about the environment.

In Paden (2012: 18) study, environmental competencies comprise identify environmental issues, ask relevant questions, analyze environmental issues, investigate environmental issues, evaluate and make personal judgements about environmental issues, use evidence and knowledge to defend positions and resolve issues, and create and evaluate plans to resolve environmental issues. On the other hand, based on second and third round Delphi studies, according to the experts, EL competencies that come to the forefront are knowledge and understanding about environment issues, responsibility towards the environment, awareness of environmental issues, motivation towards the environment, morals and ethics regarding environmental issues, social engagement related to the environment, intention to act to protect the environment, positive behavior towards the environment, sustainable knowledge about the environment, and concrete sustainable activities towards the environment. EL includes awareness, knowledge, attitude, skills, and participation to develop positive environmental behaviors (Wisconsin Department of Public Administration, 1991). In Roth's (1992) study, in EL there are six major areas including environmental sensitivity, knowledge, skills, attitudes and values, personal investment and responsibility, and active involvement. Another similar study is also shown (Wong, Afandi, Ramachandran, Shuib and Lian, 2017) that EL includes four components; ecological knowledge (knowledge), disposition (affect), issue identification and action strategy (cognitive skills) and pro-environmental behaviour (behaviour). In Kaya and Elster's (2018a) study, EL includes awareness and responsibility toward the environment, as well as, to be optimistic toward the environment.

4.2.3. Which concepts and contexts are included in the framework of EL? And which teaching methods and extra-curriculum activities are used for the development of EL?

In recent decades, scientific development has an important influence on humanity, quality of life, the sustainable development of the planet (UNESCO, 2010). Curricula and textbooks are important for students to be aware of scientific development in the field of science, especially in biology. Moreover, as Brugeilles and Cromer (2009) state, textbooks including the general components of the curriculum are a basic teaching resource and form the basis of assessment. Therefore, revising of textbooks and curriculum is crucial for development of EL. According to results of three rounds Delphi study, the following topics should be included in the curriculum and textbooks for the development of EL:

- Nature of Environmental Concepts (Ecosystem, ecology, and natural resources, etc.),
- Examples of Environmental Problems (Global warming, Climate Change, and Endangered species, etc.),
- Sustainability (Sustainable development and future, etc.),
- Social Perspectives (Interrelationship of Environment, Society, and Technology, etc...),
- Environmental Perceptions (Attitude, responsibility, morals, etc.),
- Examples of Environmentally-Friendly Behavior (such as saving and protecting natural resources, etc.),
- Solutions for Environmental Problems (Recycling and Renewable Energy, etc.).

According to analysis of content in the traditional curriculum in European Union, the following environmental issues were addressed in upper secondary education (Stokes, Edge and West, 2001: 18):

- Environmental policy and law,
- Scientific principles and analysis of environmental phenomena;
- Social and economic factors, determinants or indicators of environmental issues;
- Planning, land and resource management;
- Ecology and ecosystems.

On the other hand, Nam (1995: 119) also reports that there are 8 hidden units including in the Korean curriculum: "Meaning of planet environment", "the social context and causes of environmental problems", "environmental problems and resources", "overview of environmental problems", "environmental problems in Korea", "globalization of environmental problems", "environmental hygiene", "environment preservation efforts". Another study is reported by Gilavand, Moosavi, Gilavand and Moosavi (2016), even though it is paid most attention to the component of "control and prevention of diseases" (21.10%), however, it is not paid attention to the component of "mental health" in the science textbooks of Junior High School in Iran. Omran and Yarmohammadian (2018: 115) indicate that when the EL curriculum is discussed from a broad perspective, it should include three main components of knowledge, skills, and attitudes with an integration approach that leads to achieve EL in form of environmental science, practical ethics, familiarity with the valued and cultural concepts of environment, changing attitudes toward it, attending in the conservation of the environment, having awareness of using resources appropriately and a lifestyle compatible with the environment, making the accurate decision for solutions of environmental issues and having sensitivity about them, identifying and analyzing environmental issues and inventing methods to produce solutions of the problems. Moreover, Chen (1997) summarize curriculum in the 21st century that integration of themes, such as global issues, environmental issues, citizenship education, social issues, etc., might form the backbone of the curriculum in the curriculum development process. Consequently, it is seen that most common concepts and contexts are "environmental problems", "social perspectives", and "nature of environmental concepts". However, more details of "sustainability", "solutions for environmental problems", and "examples of environmentally-friendly behavior" should be elaborated in the future curriculum.

In addition, an effective curriculum should allow incorporating socialization into the academic disciplines (National Research Council, 2002). Therefore, experts mention that the topic "social perspectives" should take part in the curriculum and textbooks for the development of EL. However, in the curriculum, not only social perspectives but also different disciplines like economy, geography, history together with information technology might be used to provide solutions for complicated environmental problems (Mohammed, 2006).

Additionally, nowadays not an only traditional curriculum but also teaching methods are not able to meet environmental needs, therefore, new methods are innovated to solve environmental problems (Omran, 2014). By learning and using new teaching methods, teachers might foster to improve the learning environment of students (Pour, Heydari and

Khiltash, 2016). According to three round Delphi studies, for the development of qualified EL, teachers should use teaching methods including:

- Experiment,
- Project based learning,
- Context-based learning,
- Problem-based learning,
- Different discussion methods,
- Inquiry-based learning,
- Out-of-school activities,
- Hands-on experience,
- Collaborative learning

Therefore, science teachers should design classroom environments in which students can express their thoughts, and make class discussions (Kaya and Elster, 2017). However, it is argued by Šorgo and Kamenšek (2011) that one of the most significant problems is that teaching is mostly about environmental subjects, however, it is not using the environment in proactive and active inquiry- and problem-based learning.

According to first round Delphi study, for the development of EL, it is important to be aware of the importance of the following extra-curricular activities:

- Watch TV programmes about environment,
- Visit web sites of environment organizations,

- Participate in environment club and activities,
- Visit museum of science and the arts, and
- Visit field trips and excursions.

However, according to second and third round Delphi studies, it is important to be aware of the importance of the following extra-curricular activities:

- Visit web sites of environment organizations,
- Participate in environment clubs and activities,
- Visit museums of science and the arts,
- Field trips and excursions.

Kaya and Elster (2018b) mention that "extra-curricular activities" have the most significant positive impact on EL among students in Singapore, Estonia and Germany. In addition, according to the results of second and third round Delphi studies, for the development of EL, it is crucial to be aware of the importance of extra-curricular activities (ECA), such as; visiting web sites of environmental organizations, participating in environmental clubs, visiting science and art museums, and taking field trips. The co-existence of ECA and in-school environmental education is fostering each other and is making education productive (Muranen, 2014). ECA not only have a positive effect on achievement at different academic levels (Derous and Ryan, 2008; Wang and Shiveley, 2009; Manlove, 2013; Bakoban and Aljarallah, 2015), but also promote student passions, skills, cooperation, and communication with their peers (Education Bureau, 2012; Simoncini and Caltabiono, 2012). Moreover, ECA have a positive effect on EL (Kaya and Elster, 2018b). In this study, suggestions are shared about ECA examples for the development of EL based on expert opinions.

4.2.4. Who is responsible for the development of qualified environmentally literate individuals? And what should be done?

Institutions/social groups that have responsibility for the development of qualified environmental literate individuals are universities, states, ministries of education, public departments, municipalities, industries, citizen associations and media. People who are responsible for the development of qualified environmental literate individuals are families, individuals, educators, academics, scientists, teachers and policy makers. However, individuals who do not have responsibility for the development of EL are friends, employees who work at schools, country administrators, entrepreneurs, business people, and artists.

On the other hand, teachers and families have opportunities for children to engage exploration and discovery in nature (Harper and Manning, 2013). For enhancing the development of qualified EL, the families and teachers;

- inform their children about environmental issues,
- support their children to gain moral and ethics towards the environment,
- support their children to gain attitudes towards the environment,

Moreover, governments include more environmental topics and their practice in science curricula and support the qualification of their teachers. In addition, public media (such as newspapers, TV etc.) supports individuals to learn about environmental issues. A similar finding is also stated by Kukkonen, Kärkkäinen and Keinonen (2012) that university students select television, newspapers and internet as the more important sources of knowledge on environmental issues. According to Kurtdede Fidan and Selanik Ay (2016), both teacher candidates and teachers might be informed about environmental literacy in the teacher training programs and in-service training activities, as well as, parents, school communities and non-governmental organizations might participate in the activities related to operational EL. Furthermore, although EE has been the part of the school curriculum, it is needed the practical approaches for developing sustainable implementation and the promotion of EA among the non-governmental organizations by attendance in environmental activities (Anbalagan and Shanthi, 2015). According to this dissertation, non-government organizations should also support individuals to take part in social, civil, and/or societal initiatives.

4.2.5. The determination of what teachers should do to their experiences and qualifications as environmental STEM literate individuals

The results of second Delphi study concluded that there is a consensus about ‘having and updating content knowledge about environmental issues’, ‘following the development of environmental technologies, and applying them in class.’ There is an additional agreement about ‘having and developing pedagogical competencies for the development of teachers' experiences and qualifications as environmental STEM literate individuals’. Experts believe that the importance of teachers' having knowledge about the pedagogical knowledge as well as environmental knowledge and updating them. Teaching skills and a teacher's disposition are important for the development of qualified environmentally literate individuals (Kaya and Elster, 2018b). Therefore, it is necessary to focus on teacher training and professional development (National Environmental Education Advisory Council, 2015). In particular, science teachers should update their Pedagogical Content Knowledge (PCK) and their experiences in the light of the increasing attention concerning the importance of Science, Technology, Engineering and Mathematics (STEM) Education. A robust STEM PCK ensures that teachers have the necessary knowledge to identify and measure their students' development of concepts related to STEM (Allen, Webb and Matthews, 2016). Teachers have knowledge of both the environment and STEM, and gain experience in integrating these two concepts into each other. By this means, Science Education might meet expectations of present and future generations.

On the other hand, it is thought that the concept of STEM education will be more specifically addressed for more qualified and specific STEM education. The framework of 'Science' in STEM is very broad for this reason, it may be predicted that new nomenclature related to STEM will increase to develop the applications that reveal the specific relation of the different branches of science. Else, different and new dimensions are adding into STEM education. STEAM (Science-Technology-Engineering-Art-Mathematics) is a good example to reveal the new dimension, which is the art added in STEM education and its framework also is widened. For instance, between 2011 and 2015, the Korean government decided to include STEAM (Science, Technology, Engineering, Arts, and Mathematics) education to education policy (The Korean Ministry of Education, Science and Technology, 2011, as cited Hong, 2017). The NFS has also integrated concept of computing into the STEM education (STEM+C) (National Science Foundation, 2018). Moreover, it is stated that whether the E in STEM is seen as enquiry, ethics, environment or engineering, there is a need for incorporating this dimension into their approach to STEM education (Blackley and Sheffield, 2016). This study also attempts to integrate the concept of the environment into the framework of the STEM.

4.3. Key Message

- EA and EO have a positive effect on the science achievement; but ER has a negative effect on it. Therefore, for improving students' both academic success and average of EL, students should gain environmental responsibility.
- Studies have shown that students view "air pollution", "global warning" and "greenhouse gases" as the most important environmental issues. However, German students in this present study, had the lowest awareness of "use of GMO" in 2006 and 2015 PISA data.
- The Study-1 based on PISA showed there is a significant relationship between EL and the number of musical instruments/books at home (SEC). Oral and McGivney (2013) mention that one of the factors thought to affect student achievement is having books at home. However, in the Study-3 (comparative study), "socio-economic characteristics" is not a meaningful determinant in EL in Germany and Singapore.
- "Attitude towards school", has a positive impact on the EL of German, Estonian and Singaporean students. This effect has been achieved for Estonian and Singaporean students, but it is meaningless for German students. Verešová and Malá (2016) mention that 'the attitude toward school and learning' is an important predictor of achievement.
- It is seen that the dimension that is related to the teacher has the most negatively effect on EL. The first study's results provide evidence that there is a significant relationship between teachers adapting lessons to their students' needs and knowledge, changing the structure of their lessons, providing individual help when students have difficulties, and explaining science ideas in every lesson and EL.
- "Extra-curricular activities" that are associated with the curriculum that have the most significant positive impact on EL among all three (Germany Singapore, and Estonia) countries' students. In a similar study, Adeyemo (2010) mentioned that out-of-school activities have an important effect on the students' physical success.
- EL has been defined by many researchers. This dissertation expands on this definition and shows that it is necessary to include concepts of morals and ethics towards the environment; knowledge, understanding, attitude, morals and ethics,

and intention and behavior towards the environment; and development of skills to evaluate data, draw conclusions, and form personal opinions in the definition of EL.

- Future EL research should include “morals and ethics”, “motivation”, and “sustainability”.
- For the development of EL, it is crucial to be aware of the importance of ECA such as visiting web sites of environmental organizations, participating in environmental clubs, visiting science and art museums, and taking field trips.
- Nowadays, science teachers should update their pedagogical content knowledge and their experiences in the light of the increasing awareness concerning the importance of STEM education. The concept of ‘environment’ should be integrated into the framework of STEM-PCK for teacher’s professional development

Chapter 5. Implications and Recommendations

In this chapter, implications and recommendations of 'large-scale assessment studies' and 'Delphi studies' are included.

5.1. Implications and Recommendations based on Large-Scale Assessment (PISA) Studies

According to the large-scale results, it might be concluded that the environmental literate individual needs awareness and responsibility toward the environment, as well as, to be optimistic toward the environment. Therefore, the knowledge and awareness levels of students should be increased to educate more environmentally literate individuals. The relationship between EL and EO is also positive and meaningful. However, it is also apparent that they are more concerned about environmental issues. Especially, it might be said that the subjects of "genetically modified organisms" and "health issues" should be more comprehensively taught as part of the science curricula in Germany and in other countries. Therefore, they should be encouraged to increase their knowledge and awareness about the environment as well as to develop positive emotions toward the environment to remove or reduce environmental concerns. Students should be informed about the effect of these on the environment, and in social terms, individuals should have raised awareness of these issues.

Increasing their optimism about the environment will contribute to higher EL. Moreover, the findings demonstrate the importance of “extra-curricular activities" to train more qualified environmental literate individuals. Therefore, more extra-curricular activities such as direct value experiences, stimulating natural phenomena in computer programs, participation in science clubs especially ecology organizations, field trips and excursions that promote the awareness and the connectedness to the nature and the environment should be included in formal education. In addition, these activities should support formal education and be implemented and encouraged in a planned manner as a complement to each other. Furthermore, while developing environment-related curricula, it should be supported to gain more responsible behaviors towards the environment. Eventually, enhancing the environmental responsibility of the students might contribute to both EL and SL.

Governments and schools should be aware of the effect of SEC on EL. Governments should provide books to students of low socioeconomic status. Science teachers should also be aware of the effect of SEC on EL and enrich the teaching methods and materials used in their lessons. For instance, the use of musical instruments by science teachers during EE may increase EL levels. Moreover, the students' interest and attitudes towards science should be improved, and students should be encouraged to read science books. Both the students and their families should be supported for the quality of the education. For example, governments should pay more attention to public education. Experts should give seminars on how parents might support their children both personally and academically. On the other hand, it is also necessary to increase students' attitudes towards school and science. For instance, more extra-curricular activities such as computer programs and field trips should be included in formal training (Kaya and Elster, 2018b).

Teachers should allow students to access new information instead of simply sharing information with students. In addition, science teachers should design classroom environments in which

- students can express their thoughts,
- students can engage in class discussions, and
- students have access to new knowledge during EE.

Therefore, support should be provided for the development of teacher training skills for science teachers and teacher candidates. Examples for skills and competences that should be trained are how to give feedback for the academic development of the student, how teamwork should be implemented, and what to look for an effective classroom management. In addition, practical EE could be offered through in-service and pre-service education. In this way, teachers' tendency in other words, teacher’s disposition to teach towards teaching can be improved. In this process, teachers and teacher candidates should be encouraged to use a constructivism approach in teaching and learning and ensure an effective students’ participation in this process. Moreover, the teaching profession starts with pre-service training and continues with in-service training (Kaya, 2011; Kaya and Gödek, 2016). Therefore, teacher training and practices should be developed to teach environmental issues. Similarly, teachers should also be supported during in-service teacher education. Especially science and biology teachers should be informed about these issues during their in-service training.

Ultimately, it is important that teachers are aware of the changing roles of EE, that they design student-centred education and/or that they facilitate inquiry-based learning in the classroom environment. Moreover, it is important that improvements to be made to secure the professional development and science process skills of the students. Lastly, the importance, scope and competencies of EL should be determined more clearly to ensure a higher quality of SE.

On the other hand, the reasons for the positive effects of the attitudes of students in Estonia towards the school, science and science content knowledge to EL should be investigated in more detail. SE applications should be investigated which lead to positive attitudes towards students in education. In this area, Estonia's education system can lead to improved EL for students by identifying good examples of the SE system in particular.

5.2. Implications and Recommendations based on Delphi Studies

Based on the first Delphi research results, the scope and definition of EL were revised in line with the opinions of experts. Moreover, the competencies of EL were enumerated. Therefore, our results should not only guide curriculum developers, researchers, and stakeholders, but also suggest what teachers should do to educate qualified environmentally literate individuals.

Based on the results of this research, the new definition of EL might be:

"knowing and understanding environmental issues; having attitudes, concerns, morals, and ethics towards the environment; having the ability and intention to act with environmentally responsible behavior; as well as having skills to evaluate data and draw conclusions to form one's own opinion."

When evaluating EL, researchers and curriculum developers should consider this definition of EL as well as the seven sub-dimensions and ten competencies. Teachers have a significant role in educating environmentally literate individuals. In the teaching process, teachers should use the project-based learning approach, varied discussion methods, out-of-school activities, and collaborative learning and expository instructional teaching. Moreover, the results of this dissertation show that teachers' professional development is a key factor that affects the development of environmentally literate individuals. Thus, EL requires qualified environmentally literate teachers.

Additional EE should become part of the academic teacher training programs in the universities. Teachers, as well as families and governments, have an important responsibility for directing and encouraging students to attend extra curriculum activities such as participating in environment club and activities, visiting science museums, and utilizing out-of-school environments. In addition, curriculum developers, program developers, and authors should include the concepts of environmental perceptions, examples of environmentally-friendly behavior, environmental problems and their solutions, sustainability, and social perspectives to enhance environmental science curricula and books.

Finally, the development of quality EL education will depend on the quality of education and teacher training, quality of science curricula and textbooks in school systems, family engagement, as well as initiatives from environmentally sensitive governments and non-government organizations.

Additional EE should become part of the academic teacher training programs in universities. In particular, the concept of "environment" should be integrated into the framework of STEM-PCK for teacher's professional development. The determination of $^{E+}$STEM includes three different knowledge components: E+Content Knowledge (knowledge on STEM and Environment), Pedagogical Knowledge (knowledge on how to teach environment-related STEM activities), $^{E+}$STEM-K (disciplinary knowledge required for the integration of science, technology, engineering and mathematics as environmentally friendly, in additional knowledge of the relationship between the environment and the subjects to be taught about STEM). By this means, a new educational and environmental concept, environmental-STEM-PCK, would be incorporated into teacher education. Then, future research might determine the scope of $^{E+}$STEM-PCK in the light of framework of PCK and STEM-PCK and how it can be taught to teachers, thereby increasing the quality of STEM education.

5.2.1. Implications and Recommendations for Teacher Education in Light of STEM Education

The use of raw material resources with industry 4.0 will increase in speed. This situation will harm natural life more. For this reason, the knowledge and skills of students should be developed both in the field of STEM and conservation of nature and natural resources in order to achieve the desired success in the industrial 4.0 revolution. In this way, it will prevent consumption of natural resources quickly.

For this reason, the concept of the environment should be integrated into the disciplines of science, technology, engineering, and mathematics in the education of the present and future generations. In other words, STEM education and EE should be integrated (in figure 5.1).

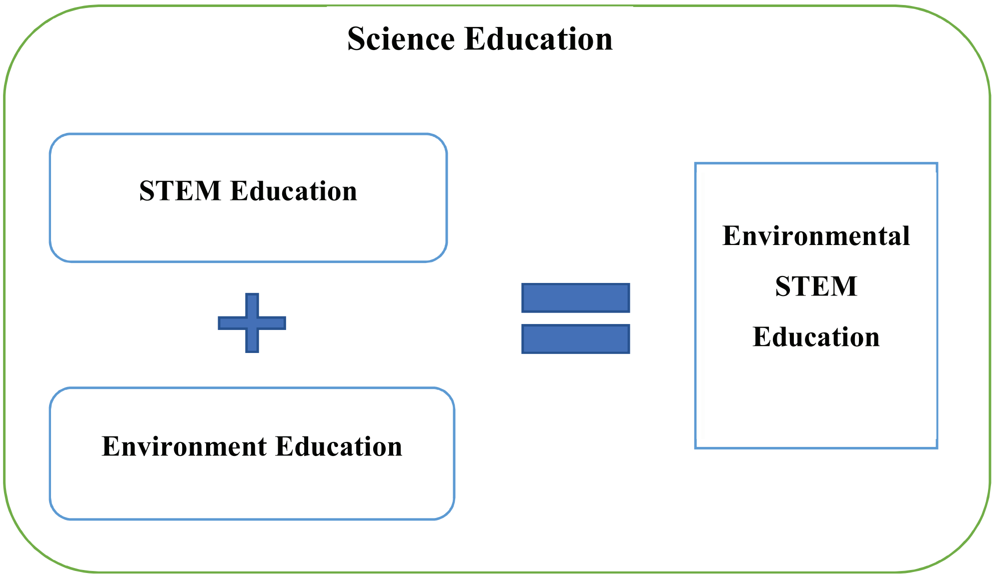


Figure 5.1. Scope of Environmental STEM Education

The purpose of environmental STEM education that is the specific field of STEM education, is to protect environment-conscious and existing natural resources while integrating science, technology, engineering and mathematics are related to each other. It is aimed to produce innovative thoughts and materials without ignoring the living beings of nature and nature during interdisciplinary studies are taking place in the field of the STEM. For example, while students develop innovative products within environmental STEM education, they should aim to use existing natural resources in a conservative way, without neglecting the environment. It is also expected that after completing the lifetime of the innovative products, they should be designed to recycle again.

5.2.1.1. *The Improtance of Environmental STEM Education*

Nowadays, it is observed that in the global sense, international studies and projects on both the development of the industry 4.0 and the protection of nature have increased. In fact, within a production process emerging with industry 4.0, it is needed raw material before production, and energy requirement during production. Then, it is used natural resources and habitats for the disposal of waste materials after completing the lifetime of materials. For this reason, while the two concepts influence each other, the present and future generations should be well-educated for not only meetings the needs of industry 4.0 but also preserving the nature. This might be achieved through environmental STEM education (in figure 5.2). In addition, environmental STEM education aims to help children to find out and develop more effective solutions to environmental problems by integrating different disciplines. In other words, it is aimed to use disciplines of science, technology, engineering and mathematics to develop environmental technologies for existing environmental problems.

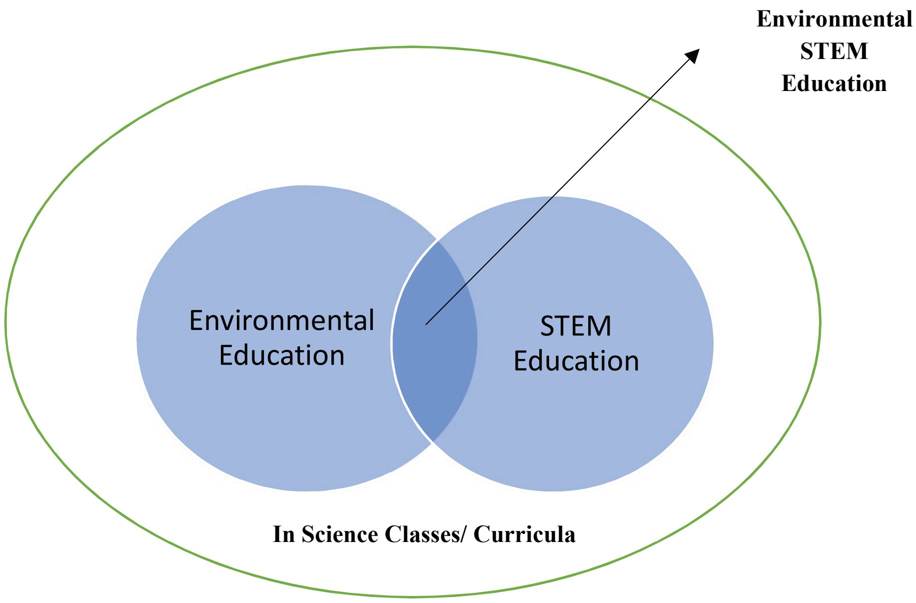


Figure 5.2. Components of Environmental STEM Education

Both the developing the theoretical framework and transferring into practice are crucial issues for effective teaching in environmental STEM education. The NAAEE develops programs to integrate environmental education into STEM learning for students (Kunkle, 2018). The researchers/ educators/ teachers should take over more responsibility for the development of environmental STEM education.

Furthermore, rapidly evolving technology has quickly become a reflection of education. One of the best examples of this is STEM education. Therefore, STEM education, which is one of the important components of education nowadays, is included to science curricula. However, some questions are raised for the quality of STEM education: However, there are some questions that need to be answered for the quality of STEM education: Is STEM pedagogy (STEM teaching and learning) included in both teacher education programs and in-service teacher training? How to teachers gain content knowledge (especially field of science, technology, engineering, and mathematics) and STEM knowledge (how to integrate different disciplines in STEM activities)? The level of response to these questions will indicate the STEM-PCK levels of the teachers. For this reason, in order to increase the quality of the future outcome of STEM education, it is necessary to not only integrate the STEM concept into curricula but also increase the knowledge and experience of teachers who are curricular practitioners. Moreover, integration of more specific areas (ex. environment) of knowledge and skills related to the STEM PCK (ex. environmental STEM PCK) will help to accomplish the goal(s) (such as, educating qualified environmental STEM literate individuals) related to the integrated area.

STEM education has the opportunity to integrate four disciplines into a coherent teaching and learning paradigm, as well as providing students with the best opportunities to make sense of the world holistically (Lantz, 2009). Because, STEM education offers students the opportunity to realize their own potentials, improve their strengthen self-efficacy, and to support them through their social and academic integration (Elster, 2014). STEM Education focuses on students' development of skills such as 21st-century skills, innovation skills, cooperative learning and teamwork, problem-solving (Flanders State of Art, 2018). Moreover, quality of STEM education is crucial for the future achievement of individuals (Stohlmann, Moore, and Roehrig, 2012). Therefore, there is a need for individuals with innovative and 21st-century skills to achieve economically desirable achievements. The education system has great responsibility to educate individuals with innovative and 21st-century skills. Nowadays, STEM education is one of the educational reforms carried out to overcome this responsibility. Policymakers in the field of education think that they will be better able to adapt to the development of industry 4.0 with STEM education. Countries have increased their economic strength globally if they have achieved the desired success in the field of the STEM. This success lead to an increase the socio-economic welfare of people.

5.2.1.2. *STEM Pedagogical Content Knowledge*

One of the things that we should not ignore in order to catch industry 4.0 targets is to avoid the rapid depletion of existing natural resources and not allow technological wastes to pollute the World quickly. For this reason, while educating individuals who will meet the expectations of the 21st Century with STEM education; they should also be educated to be individuals who know how to protect and use nature and natural resources. Therefore, the concept of the 'environment' is actually a core concept in STEM education. Existing natural resource may be used more to meet the need for more raw materials needed for industry 4.0. with increasing the industry 4.0 revolution quickly. Therefore, future generation should be aware of necessity of the environmental protection while developing and using the technology. This awareness may contribute to the reduction of daily waste as well as commercial waste especially industrial waste (such as waste batteries, electrical and electric materials, etc.). For this reason, the concept of the environment should be integrated into the disciplines of science, technology, engineering, and mathematics in the education of the present and future generations.

One of the things that should be considered for the quality of STEM teaching is the education of teachers / educators. Teacher content knowledge is one of the paramount elements of the improvement of teaching and learning (Ball, Thames, and Phelps, 2008). However, teacher education programs rarely connect content instruction with pedagogy, furthermore, if teacher candidate is not specializing in a STEM-related field, STEM content preparation in pre-service education tends to be inadequate (York, 2018). There is a similar situation in-service education. For this reason, it is necessary to increase the experience in STEM teaching of lecturers in pre-service education and educators in-service education to provide more qualified STEM education. Therefore, governments support lecturers' and educators' knowledge and expertise in STEM disciplines through recruitment, preparation, support, and retention strategies (U.S. Department of Education, 2017). Emphasis on the training of STEM educators as well as lecturers will help increase the quality of teachers in STEM education.

After Shulman introduced the concept of PCK in 1986, TPCK emerged by Mishra and Koehler by integrating the technology into the concept of PCK in 2006. Nowadays, updating this concept in line with educational reforms will contribute to the quality of teacher education.

Especially, in the field of SE, the concept of "STEM" should be integrated into the PCK in the direction of STEM-focused reforms. It is also necessary to think over and discuss about what the types of sub-knowledge that will emerge as a result of this integration, and the issue of how this concept can be included in teacher education. In this paper, it is also tried to describe STEM pedagogical content knowledge and its components.

Since STEM PCK is structured in the PCK and TPCK and their frameworks, the better understanding of PCK and TPCK, and their key components is the first requirement to better understand the STEM PCK. As seen in figure 5.3, STEM PCK's components are content knowledge, pedagogical knowledge and STEM knowledge. Content knowledge includes knowledge of both science curricula and content specific (STEM); Pedagogical knowledge includes general and specific pedagogical knowledge; STEM knowledge includes disciplinary knowledge and knowledge of the relationship between each the subjects to be taught about STEM.

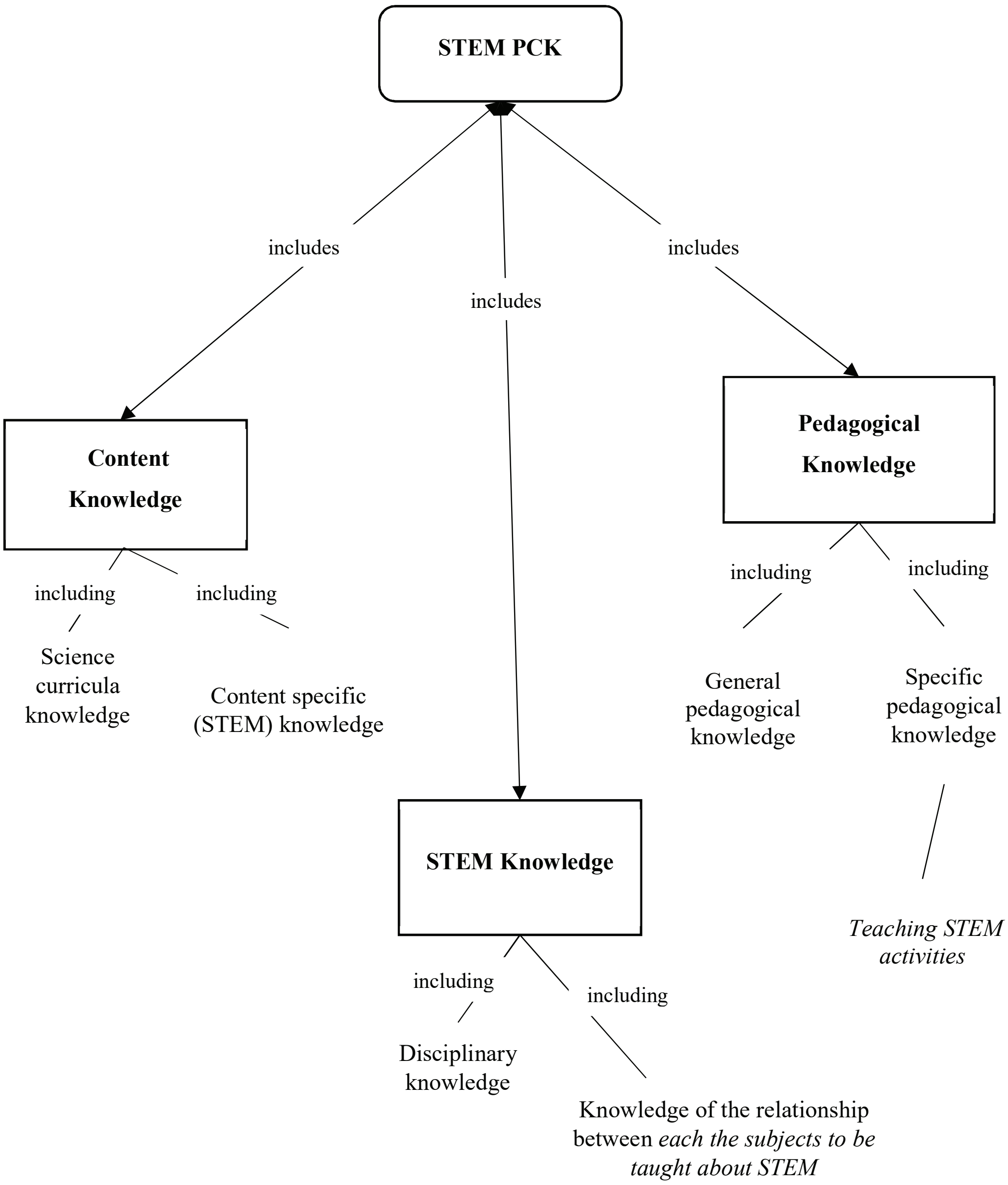


Figure 5.3. STEM Pedagogical content knowledge and its components
(Adapted from Shulman 1986 and 1987; Mishra and Koehler, 2006)

For effective STEM teaching, the STEM PCK should first be integrated into the STEM teaching. In addition, STEM teaching consists of four knowledge components: knowledge of science curricula, assessment of STEM literacy, students' understanding of STEM, and knowledge of instructional strategies (in figure 5.4).

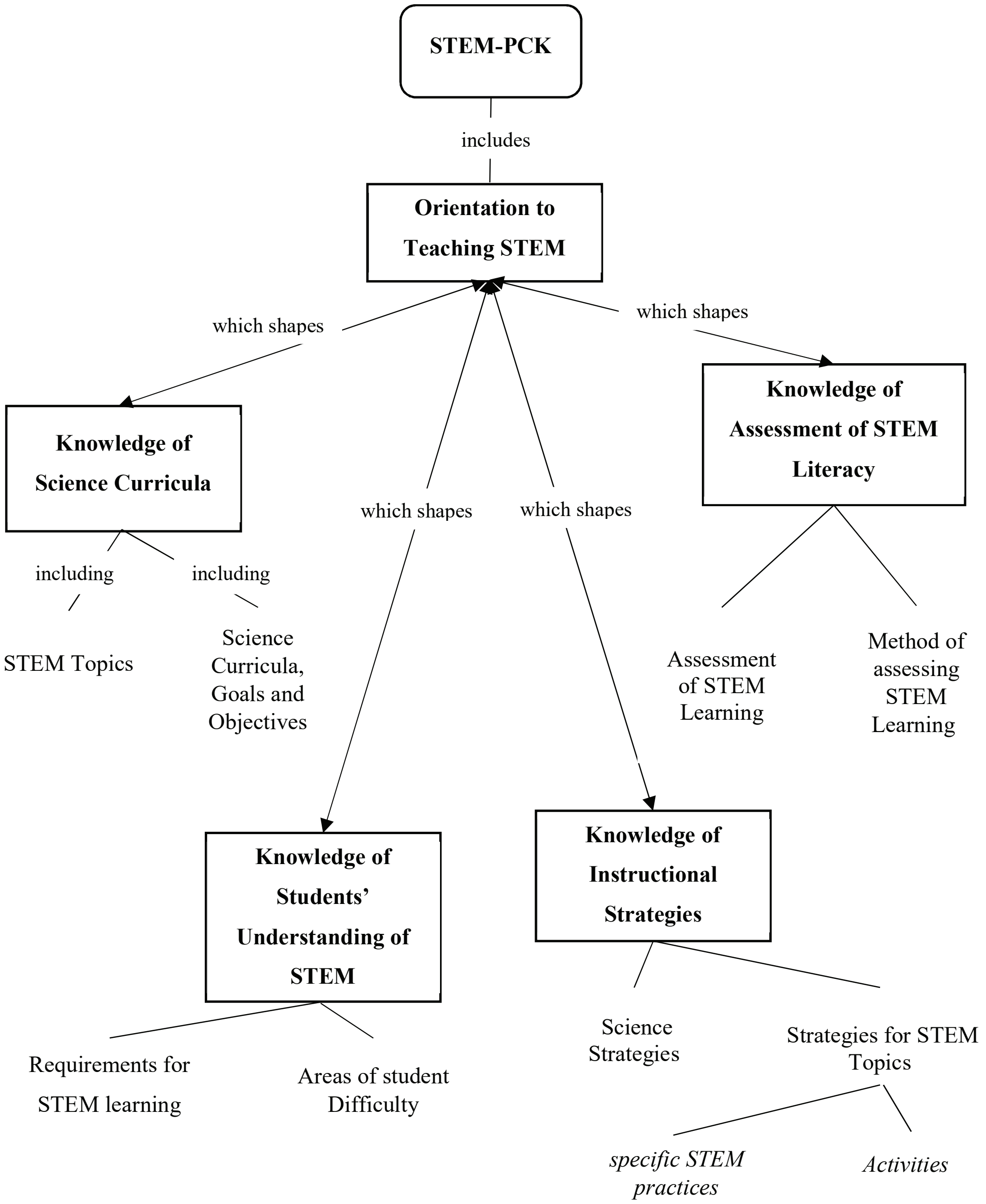


Figure 5.4. Components of STEM pedagogical content knowledge for STEM teaching (Adapted from: Magnusson, Krajcik and Borko, 1999)

5.2.1.3. A New Vision in Science Education: $^{E+}$STEM PCK

In the present and future century, individuals should be able to integrate knowledge and skills in different disciplines to solve problems they face, not just to improve memorizing ability for real and true learning. For this reason, teachers who are going to gain skills from individuals need to have the desired level of STEM PCK. On the other hand, integration of more specific areas (ex. environment) of knowledge and skills related to the STEM PCK (ex. environmental STEM PCK) will help to accomplish the goal(s) (such as, educating qualified environmental STEM literate individuals) related to the integrated area.

Pedagogical knowledge is used to facilitate effective teaching practices in ways that aim to make learning more accessible to students (Hudson, English, Dawes, King and Baker, 2015). When pedagogy is most successful, faculty and students work together toward the shared purpose of learning (Association of American Universities, 2018). STEM education will be more specifically addressed for more qualified and specific STEM education because of the evolvement of the framework of 'Science' in the STEM. In this study, while the $^{E+}$STEM PCK includes within the framework of STEM PCK, STEM PCK includes also within framework of PCK (in figure 5.5). For this reason, it is necessary to be aware of what the STEM-PCK and PCK are for the better understanding of the $^{E+}$STEM PCK.

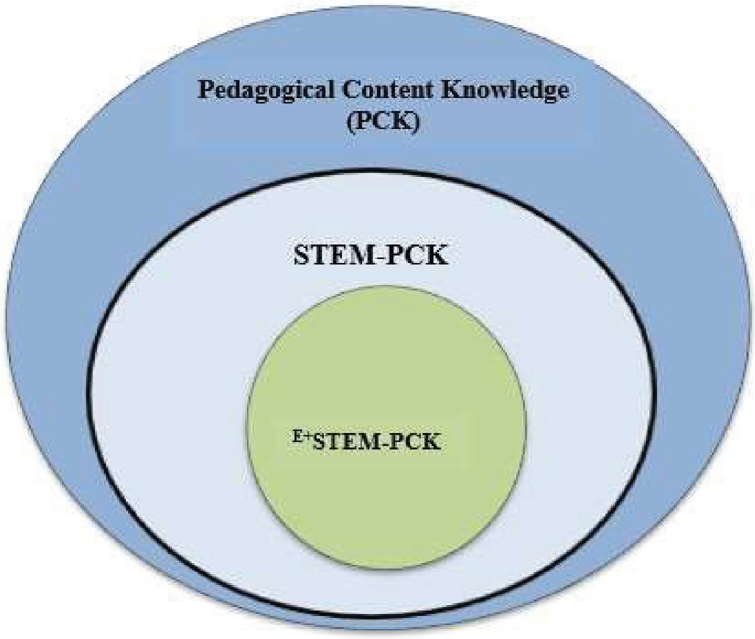
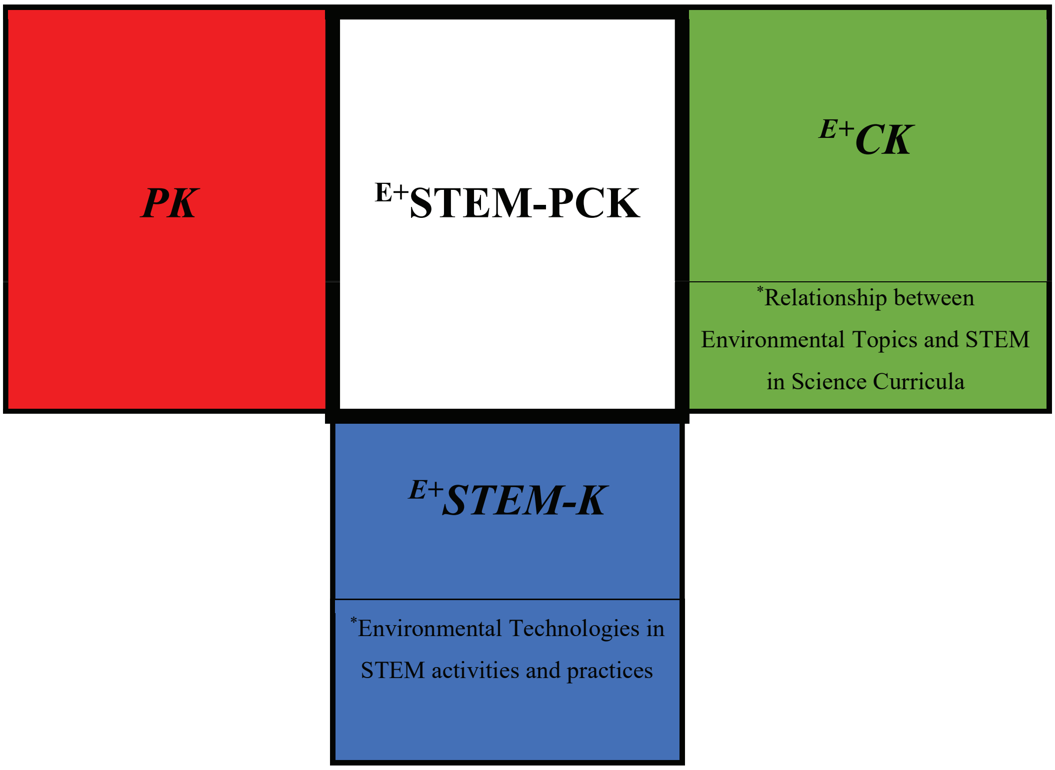


Figure 5.5. Integration of Environment and STEM into PCK

$^{E+}$STEM PCK have 3 different knowledge components (in figure 5.6):

> *"$^{E+}$Content Knowledge (knowledge on STEM and Environment), Pedagogical Knowledge (knowledge on how to teach environment-related STEM activities), $^{E+}$STEM-K (disciplinary knowledge required for the integration of science, technology, engineering and mathematics as environmentally friendly, in additional knowledge of the relationship between the environment and the subjects to be taught about STEM)."*



Note: When colors of blue, green and yellow are mixed, the white color occurs.

Figure 5.6. Components of $^{E+}$STEM pedagogical content knowledge for science teaching

The development of $^{E+}$STEM PCK by teachers especially science teachers is vital for qualified STEM teaching. In this figure 5.6, teachers' knowledge, which is equally important, has 3 core components. It is also tried to describe a framework for STEM pedagogical content knowledge based on environment called environmental STEM pedagogical content knowledge in this part. Shulman (1986) described the combination knowledge of pedagogy and content as pedagogical content knowledge. In this paper, we described the combination knowledge of pedagogy, content (not only fields of STEM but also environment), and associating disciplines with each other (in figure 5.7).

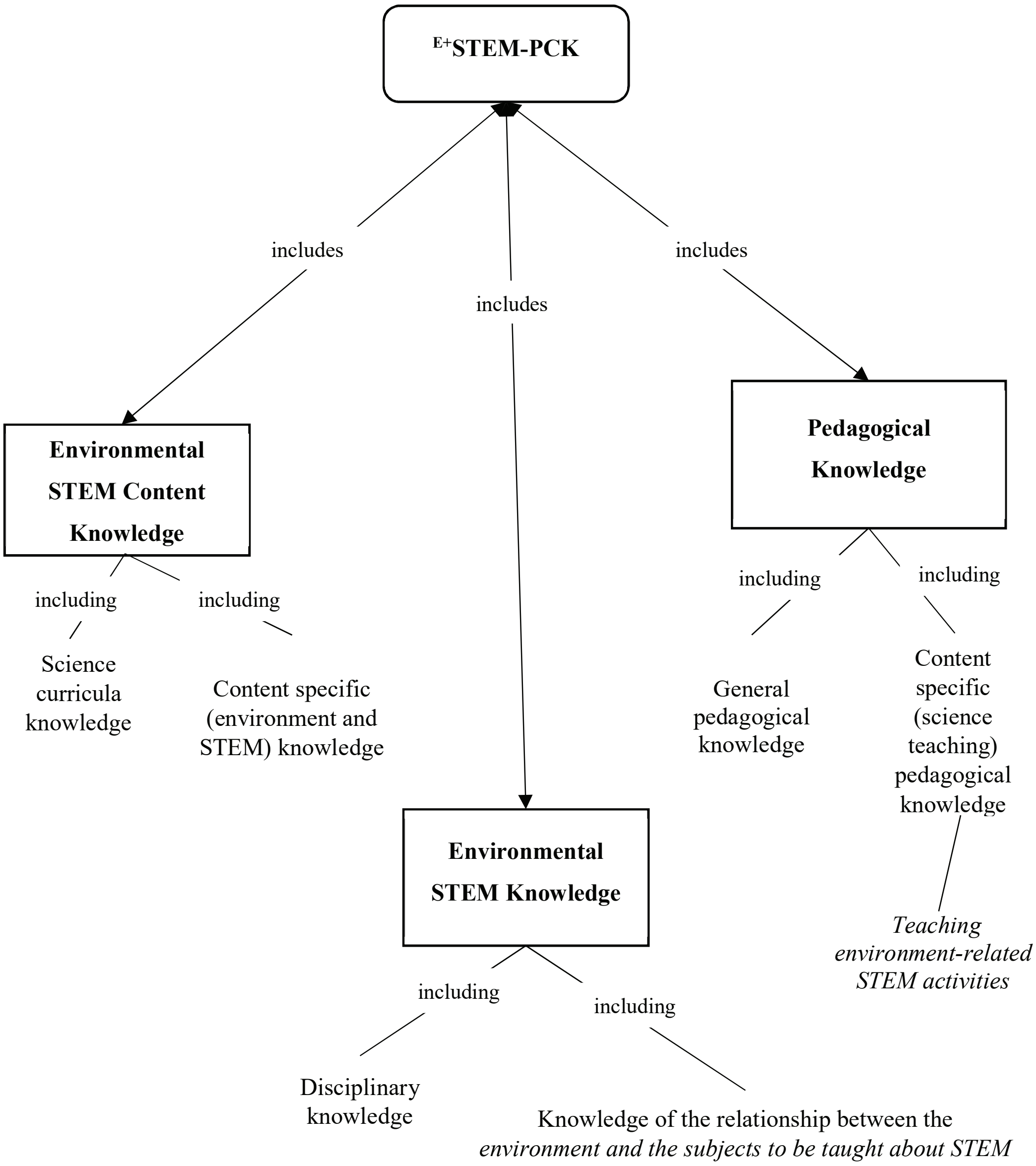


Figure 5.7. Environmental STEM PCK and its components

5.3. Implications and Recommendations for Further Research

The inclusion of EL within the framework of international large-scale research might universally expand awareness of EL. In addition to, the exploration of educational policies related to the environment that different countries have applied in SE might contribute to the development of environmentally literate individuals.

Moreover, the integration of international large-scale research and qualitative research might contribute more to EL universally. In this way, revision and updating the EL within the educational system, which is continuously developing, might be realized more effectively. Finally, educational policies, professional development of teachers and adult education should be reconsidered by obtaining the results and suggestions in this study. In further studies related to EL, it should be also taken into consideration the framework of the environmental literature, which is obtained from expert's opinions.

Ultimately, researchers and teachers might support the development of the framework of environmental STEM education in school and environmental STEM pedagogical content knowledge.

5.4. Key Message

Solutions for educating more qualified EL

- It might be said that the subjects of "genetically modified organisms" and "health issues" should be more comprehensively taught as part of the science curricula in Germany and other countries.
- More extra-curricular activities such as direct value experiences, stimulating natural phenomena in computer programs, participation in science clubs especially ecology organizations, field trips and excursions that promote the awareness and the connectedness to the nature and the environment should be included in formal education.
- While developing environment-related curricula, it should be supported to gain more responsible behaviors towards the environment.
- Governments should provide books to students of low socioeconomic status.
- Experts should give seminars on how parents might support their children both personally and academically.
- Teachers should allow students to access new information instead of simply sharing information with students.
- Teachers and teacher candidates should be encouraged to use a constructivism approach in teaching and learning and ensure an effective students' participation in this process.
- The new definition of EL based on our results is:

  "knowing and understanding environmental issues; having attitudes, concerns, morals, and ethics towards the environment; having the ability and intention to act with environmentally responsible behavior; as well as having skills to evaluate data and draw conclusions to form one's own opinion."
- A new educational and environmental concept, Environmental-STEM-Pedagogical Content Knowledge ($^{E+}$STEM-PCK), would be incorporated in teacher education.

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LIST OF TABLES

LIST OF FIGURES

SECTION 2. PUBLICATIONS

In this section, ‘research field-I: international large-scale asssessment studies based on PISA Data’ ‘and ‘research approach-II: DELPHI study’ are included.

2.1. Publications related to the thesis

2.1.1. Research File-I: International Large-Scale Assessment Studies

Kaya, V.H. and Elster, D. (2018). German Students’ Environmental Literacy in Science Education Based on PISA Data, *Journal of Science Education International*, *29* (2), 75-87.

Kaya, V.H. and Elster, D. (2017). Change in the Environmental Literacy of German Students in Science Education between 2006 and 2015, *The Turkish Online Journal of Educational Technology, Special Issue for INTE 2017*, 505-524.

Kaya, V.H. and Elster, D. (2018). Comparison of the Main Determinants Affecting Environmental Literacy Between Singapore, Estonia and Germany, *International Journal of Environmental and Science Education, 13* (3), 1-17.

Kaya, V. H. and Elster, D. (accepted). Dimensions Affecting Environmental Literacy, and Environmental Perceptions Influencing Science Literacy, *International e-Journal of Educational Studies,3*(6), 1-9.

2.1.2. Research File-I: International Large-Scale Assessment Studies

Kaya, V.H. and Elster, D. (Submitted). A Critical Consideration of Environmental Literacy: Concepts, Contexts and Competencies, *Sustainability*.

Kaya, V. H. and Elster, D. (2019). Environmental Science, Technology, Engineering, and Mathematics Pedagogical Content Knowledge: Teacher's Professional Development as Environmental Science, Technology, Engineering, and Mathematics Literate Individuals in the Light of Experts' Opinions, *Journal of Science Education International, 30* (1), 11-20.

2.2. Other Publications (without the framework of the thesis in the doctoral education)

Gödek, Y., Polat, D., Kaya, V. H. (2018). *Fen Bilgisi Öğretiminde Kavram Yanılgıları: Kavram Yanılgılarının Tespiti-Giderilmesi ve Uygulamalı Örnekler (Genişletilmiş 3. Baskı),* Pegem Akademi, Ankara.

Kaya, V.H., (2018). Are Homework and Tutoring Necessary for Increasing Science Achievement? *Anatolian Journal of Teacher*, 2 (1), 48-62.

Godek, Y., Polat, D. and Kaya, V.H. (2018). *Misconceptions in Science Education*, Pegem Akademi Publisher, Ankara.

Kaya, V.H. (2017). The Impact of Reading Skills on Science Literacy, *Journal of National Education, 215,* 193-207.

Kaya, V.H. ve Dogan, A. (2017). Determination and Comparison of Turkish Student Characteristics Affecting Science Literacy in Turkey According to PISA 2012, *Research Journal of Business and Management, 4* (1), 34-51.

Polat, D., Gödek, Y., and Kaya, V.H. (2017). According to PISA 2012, The Determination of the Relationship Between Mathematical Literacy and Mathematical Content Knowledge and Science Literacy: Turkey Sample, *Research Journal of Business and Management, 4* (1), 84-89.

Kaya, V. H. (2017). Determination of the Relationship Between Information Technology, Student Emotions and Science Literacy in the Light of Emotional Intelligence. *Journal of Computer and Education Research, 5* (10), 194-217.

2.1.1. Research Filed-I: International Large-Scale Assessment Studies based on PISA Data

Kaya, V.H. and Elster, D. (2018). German Students' Environmental Literacy in Science Education Based on PISA Data, *Journal of Science Education International, 29* (2), 75-87.

Kaya, V.H. and Elster, D. (2017). Change in the Environmental Literacy of German Students in Science Education between 2006 and 2015, *The Turkish Online Journal of Educational Technology, Special Issue for INTE 2017*, 505-524.

Kaya, V.H. and Elster, D. (2018). Comparison of the Main Determinants Affecting Environmental Literacy Between Singapore, Estonia and Germany, *International Journal of Environmental and Science Education, 13* (3), 1-17.

Kaya, V. H. and Elster, D. (accepted). Dimensions Affecting Environmental Literacy, and Environmental Perceptions Influencing Science Literacy, *International e-Journal of Educational Studies,3*(6), 1-9.

The main aims of these studies are to determine the factors that affect the environmental literacy of 15-year old students in Germany and to present core results of the change in environmental literacy of German students by analysing PISA 2006 and 2015 data. Moreover, other purposes are to determine and compare the variance of the main factors affecting the environmental literacy of the fifteen-years-old students studying in Singapore, Estonia and Germany, and to determine the effects of environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) on SL.

Prof. Dr. Doris ELSTER, who is my supervisor, supports me for preparing these publications. I clearly indicate that I contribute to these studies with my own academic skills and abilities. These studies were presented to the following international and national congress/conference.

Participations in Congress and Conference

Kaya, V.H. and Elster, D. 19-21 May 2017, German Students' Environmental Literacy as a Starting Point for Science Teacher Education, International Teacher Education and Accreditation Congress, Istanbul/TURKEY (Oral Presentation).

Kaya, V.H. and Elster, D., 2017, Change in Environmental Literacy of German Students in Science Education between 2006 and 2015, International Conference on New Horizons in Education, July 17-19 2017, Berlin/GERMANY (Oral Presentation).

Kaya, V.H. and Elster, D. (2018). Comparison of the Main Determinants Affecting Environmental Literacy Between Singapore, Estonia and Germany, *Proceeding Book of New Perspectives in Science Education International Conference (Edition 7),* March 22-23 2018, Florence/ITALY (Oral Presentation).

Kaya, V.H. and Elster, D. (2018). Study about Main Dimensions that Influence on Environmental Literacy and the Influence of Environmental Perceptions on Science Literacy, 13th National Science and Mathematics Education Congress, 4-6 October 2018, Denizli/TURKEY (Oral Presentation).

2.1.1.1. German Students' Environmental Literacy in Science Education Based on PISA Data

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ABSTRACT: The main aim of this study is to determine the factors that affect the environmental literacy of 15-year old students in Germany. The data were based on findings from the PISA 2015 of German students (N=6,504), which were published on the official PISA site (http://www.pisa.oecd.org). According to the results, there was a positive and meaningful relationship between environmental literacy (EL) and environmental optimism (EO) at a low level. There was a meaningful relationship between EL and socio-economic characteristics (SEC). Moreover, SEC has a large effect on the EL. There was significant relationship between both classic literature and books on art, music or design that students have at home, number of musical instruments at home and EL. However, there was no significant relationship between both books of poetry and books to help with school homework that students have at home and EL. Another result shows that there was a significant relationship between some of the selected teaching characteristics (frequency of adapting lessons, teachers' providing individual help, teachers' explanations of scientific ideas and teacher changing the structure) and EL while there was no significant relationship between EL and teacher's continuing frequency of teaching. Recommendations for the promotion of environmental literacy in schools are discussed.

KEYWORDS: environmental literacy, environmental education, PISA, science education

INTRODUCTION

In 2005, UNESCO launched its Decade of Education for Sustainable Development (2005-2014). In this decade, educational institutions in Germany increased their efforts to educate students for a more sustainable future. In the PISA 2015, however, the scientific literacy of German students reached an average of 509 points, 16 points over the OECD average. On the PISA 2000, their average was 487 points, 13 points below the OECD average. Comparing these two outcomes raised the following idea about this positive change on SL. According to PISA data, it was determined that certain factors must have a positive and/or negative affect on environmental literacy. Therefore, the purpose of this study was to determine the relationships between the environmental optimism (EO), socio-economic characteristics (SEC) of the participating students, teaching characteristics (TC) and environmental literacy (EL) of 15-years-old students in Germany. The data were based on the German sample of PISA 2015. The following sections will discuss EE in Germany's educational system.

Educational System and Environmental Education in Germany

In our globalized world, social life is more and more determined by the natural sciences and the technologies. The task of SE is to educate citizens who are able to participate in a challenging world (Bybee and Fuchs, 2006). The goal of SE is not only to educate future scientists, but to teach scientific literacy to all students (Roberts, 2007). These considerations form the basis for the National Educational Standards for secondary level biology and the other natural sciences (KMK, 2005). These standards constitute a general recommendation that all schools help students achieve a common level of learning (Barton, 2009). In 2003-2004, the Council of Ministers (KMK) developed National Educational Standards for Science (biology, chemistry and physics) for grades 9-10 in secondary school, and in 2007, additional standards for the end of upper secondary school in biology, chemistry and physics for all 16 German federal states (OECD, 2010).

An introduction to Germany's educational system will allow for a better understanding of the importance of national education standards. Therefore, the following section will discuss Germany's educational system.

Primary and secondary schools depend on local governments, and high schools (vocational schools) depend on state governments. The management and regulation of the educational system is the responsibility of the states (Bal and Basar, 2014). All children who are six years old are required to go *Grundschule* (primary school) for four years (Venter, 1987; Hainmüller, 2003). In Germany, schools called *Realschule* are on the level of *Sekundarstufe* 1 (lower secondary schools) after primary school, and besides them, *Gymnasium* schools are also included on this level (Kocak and Cobanogulları, 2016). Germany's educational system is a bit complicated because the secondary level is divided into two levels (Hainmüller, 2003). *Realschule* is the lower secondary school and the *Gymnasium* is an academic school that combines the lower and upper secondary levels (Halász, Santiago, Ekholm, Matthews, and McKenzie, 2004). *Gymnasium* is the only type of school in Germany's otherwise very heterogeneous school system that is found in all federal states (Pant, Stanat, Schroeders, Roppelt, Siegle, and Pöhlmann, 2013).

In the *Realschule*, students are provided with the opportunity to learn about daily life and vocational life. At the *Gymnasium*, students are also given vocational training and are trained for academic careers (Kocak and Cobanogulları, 2016). In the Federal Republic of Germany, students are required to pass the *Abitur* examination in order to enter higher education institutions, in particular, to graduate from the *Gymnasium upper secondary* level (Turan, 2005).

Each of the 16 federal states has its own individual school system, educational aims, educational and administrative traditions; however, every educational administration is organized in a centralized way regarding school structure, kinds of school and curriculum (Huber and Gördel, 2006). Eurydice (2014) mentions that teaching in schools in Germany is governed by regulations of various kinds laid down by the federal states. The proposed curriculum includes knowledge about the use of materials and various teaching approaches. Moreover, with the Education for Sustainable Development initiated by UNESCO, curriculum, especially science curriculum, has been focused on educating more qualified environmental literate individuals.

On the other hand, in the last decade, educational institutions around the world especially German educational institutions attempted to increase their efforts to educate students for a more sustainable future. For this reason, the term environmental sustainable development (ESD), has evolved out of EE (Filho, 2009), meaning that EE is linked to the concept of sustainable development (Brößkamp, 1994, as cited in Schleicher, 1995). ESD concerns lifestyles, participation, values, global, and individual responsibility, and patterns of consumption and production. ESD enables sustainable action and encourages readiness to accept responsibility for one's own actions (UNESCO, 2014). Since 1996, ESD has been a field of learning and action (Haan, Schavan, Fuchs AND Bory-adams, 2007).

In 2003, the German Commission for UNESCO decided on the Hamburg Declaration. The Declaration invited governmental and non-governmental organizations in Germany to participate in an 'alliance for learning sustainability'. The purpose was to develop an action plan for the UN Decade. In 2005, the National Plan of Action was to establish the notion of sustainable development permanently in all stages of education (UNESCO, 2014). This plan was supplemented by over 60 specific educational policy measures. It includes necessary skills and competencies like critical thinking, imagining future scenarios and making decisions in a collaborative way. These competencies are necessary for environmentally literate individuals. In 2007, over 200 European and international representatives participated the conference 'UN Decade of Education for Sustainable Development – the Contribution of Europe' in Berlin, Germany, during the German Presidency of the EU Council. The primary objective of the conference was to identify the European contribution to the UN Decade. Two years later, in 2009, the 'World Conference on Education for Sustainable Development' was held in Bonn, Germany. 700 participants from 150 countries agreed to the Bonn Declaration which was launched by UNESCO and the German Federal Ministry of Education and Research. In 2014, the 'World Conference on Education for Sustainable Development: Learning Today for a Sustainable Future' in Aichi-Nagoya, Japan, marked the end of the UN Decade. It celebrated its achievements and launched the Global Action Program on Education for Sustainable Development (2015-2019).

The following section will discuss the development of the purpose of this research.

The Purpose of the Research

Literacy especially scientific literacy is of paramount importance to PISA. However, although its scientific literacy tasks include items related to environmental issues, it does not evaluate EL directly. A literature review found international empirical research on students' EL (Fah and Sirisena, 2014; Spínola, 2015) and the EL of teachers and teacher candidates (Pe'er, Goldman and Yavetz, 2007; Tuncer, Tekkaya, Sungur, Cakiroglu, Ertepinar, and Kaplowist, 2009; Yavetz, Goldman, and Pe'er, 2009; Derman, Sahin, and Hacieminoglu, 2016). Researchers have developed scales to assess EL (Ozsevgec, Artun, and Ozsevgec, 2010; Atabek-Yigit, Koklukaya, Yavuz, and Demirhan, 2014). However, it seems that there is not enough research on EL using PISA data. In the future, PISA will provide an opportunity to survey EL in different nations. Moreover, Lin and Shi (2014) suggest that further investigations are needed to refine the understanding of socio-economic influences on EL. Hollweg, Taylor, Bybee, Marcinkowski, McBeth, and Zoido (2011) believe that information about students' home situations—especially family SEC and school experience—may be relevant to understanding EL. For instance, one of the components of economic, social and cultural status in PISA appears to be the index of home possessions that includes variable of the number of books in the home (Recommendations to the National Center for Education Statistics, 2012). In this study, the relationship between the SEC and EL was tried to be determined. SEC includes income as well as subjective perceptions of education level, financial security and social status and social class (American Psychological Association, 2017). Therefore, in recent years, number of books in the household was added to SEC indexes (OECD, 2004; Taylor and Yu, 2009; Zhao, Valcke, Desoete, and Verhaeghe, 2012). Bearing this in mind, this empirical study examines EL in SE. The following sections will discuss scientific literacy as a main concept in PISA and framing the concept of EL.

Scientific Literacy as a Main Concept in PISA

Although the Paris-based Organization for Economic Cooperation and Development (OECD) sponsors PISA, both OECD members and non-OECD countries participate (Bybee and McCrae, 2011). PISA offers opportunities to improve and compare the performance of these nations' educational systems (OECD, 2003). The first PISA survey was launched in 2000 and this survey has been repeated with its focus shifting from mathematics to science to reading every three years (OECD, 2000b). Thus, PISA provides data on the specific knowledge and skills of students, schools, and nations about these forms of literacy (Dobrota, Jeremić, Bulajić, and Radojičić, 2015). Scientific literacy was the main topic of PISA 2015. International student assessments provide significant information about SE policies, programs, and practices in different nations (Bybee and McCrae, 2011). The most concrete example is the changing definition of scientific literacy. Scientific literacy was first defined by PISA 2000 as "The ability to employ scientific data, to determine questions and to obtain evidence-based conclusions for comprehending and helping make decisions regarding the natural world and the alterations made to the natural world by human activities” (OECD, 2000a, p. 76; OECD, 2002a, p. 102). PISA 2000 added "The ability to use scientific knowledge, to identify science questions, to understand the nature of scientific investigation, to use scientific evidence and to communicate these aspects of science are assessed as scientific literacy by PISA” (OECD, 2002b, p. 211). Therefore, understanding scientific concepts, the ability to adopt a scientific perspective and to think scientifically about evidence are distinctive features of science literate individuals (OECD, 2004). In PISA 2006, science was assessed more comprehensively. The main difference was the distinction between knowledge of science and knowledge about science (OECD, 2009a). In 2006, the definition of scientific literacy was:

> The scientific competency of a person and employing that competency to determine questions, to learn new scientific details, to elaborate scientific elements and to obtain evidence-based conclusions regarding scientific topics, comprehending the characteristics of science as a form of human knowledge and enquiry, awareness of how our material and intellectual and cultural environments are formed by science and technology and willingness to play a role in scientific subjects as a reflective citizen with scientific ideas. (OECD, 2006, p. 12; OECD, 2013, p. 17)

By the year 2015, scientific literacy was defined by PISA as:

> The ability to play a role in scientific matters as a reflective citizen with scientific ideas. A person with sufficient scientific competency is willing to take part in a reasoned and scientific and technological discourse requiring the scientific

> explanations of scientific matters, evaluation of scientific research and its design, and scientific interpretations of data and evidence. (OECD, 2016, p. 20)

Ultimately, scientific literacy is constantly evolving because, while the necessity of scientific knowledge, especially evidence-based knowledge, were foregrounded by PISA 2000, scientific knowledge as well as the importance and characteristics of science rose to prominence in PISA 2006. It is predicted that future discussions of SE, especially EL, will include environmental issues, their significance and their components. For this reason, international assessment research will be able to evaluate EL and scientific literacy directly.

Framing the Concept of Environmental Literacy

Human consumption, agriculture, and technology make life more comfortable and safe, but also harm the environment (Polat, Kaya, and Karamuftuoglu, 2014). Therefore, deficient individual understanding of the fundamental environmental problem is often cited as a cause of environmental deterioration (Schneider, 1997). Currently, we face extremely important environmental problems such as increased air pollution (Ivanova and Roy, 2007), extinction of plants and animals (Patz, Githeko, McCarty, Hussein, Confalonieri and De Wet, 2003), clearing forests (UNESCO-UNEP, 1992), water shortages (Goss, 2010), greenhouse gases (Chivian and Bernstein, 2010), genetically modified organisms (GMO) (Key, Ma, and Drake, 2008; Hedrick, 2001) and acid rain (Likens and Bormann, 1974). These problems affect not only human beings, but also all living things. Therefore, we need more environmentally literate individuals for a life-world, and also we expect them to adapt to the changes and dynamics of environmental resources and systems (Scholz, 2011). EL is the capacity to recognize and understand the actual ecological situation and to take appropriate action to maintain, restore and improve the health of environmental systems (Roth, 1992). EL as a part of the scientific literacy gives individuals the ability to engage with science-related issues and scientific ideas (OECD, 2013).

In 1990 the term of EL was clarified and redefined with the development of EE (Roth, 1992). However, researchers continue to present new definitions of this concept. One such definition as:

> A person competent in terms of the environment who spreads and implements primary ecological concepts and principles, knows how human activities affect the environment from an ecological perspective, possesses the skills needed to define and investigate environment-related issues and alternative solutions and adopts environmental values necessary for responsible use of environmental resources.” (Subbarini, 1998, p. 245)

As North American Association Environmental Education informs us, EL includes dispositions, knowledge, and competencies applied for the purpose of responsible environmental behavior (Daniš, 2013). Ultimately, people should be aware of nature’s laws and sensitive to environmental problems and communicate with nature through EL (Kaya and Kazancı, 2009).

This research investigated the impact of environmental awareness (EA), environmental responsibility (ER) and EO on EL. The researchers reveal the basic framework for understanding EL in the light of the PISA 2015 data. One of the components, EA, is a basic level of EE (Coyle, 2005). Development of EA prepares students to become adults who have more knowledge and understanding of the environment (David, 1974). Environmentally literate individuals have social awareness about their own actions, as well as EA (Stoller-Patterson, 2012). Another component of EL, ER, is defined as "An individual's responsible and moral approach to the prevention of environmental degradation, the solution of environmental issues and willingness to act in a positive manner for the environment" (Wenshun, Xiaohua, and Hualong, 2011, p. 992). The last component, EO, has gained significance in the field of EE (Eryigit, Tekkaya, and Sahin, 2011) because students' levels of EO as well as their EA affect their environmental concerns and this affects the global climate, the economy, and society (PISA, 2017). Finally, this research intends to contribute to a better understanding of EL by analyzing the effects of EA, ER and EO in EE.

Research Questions

The main aim of this research is to determine the factors that affect the EL of 15-year old students in Germany. More specifically, its research questions were:

- Which factors affect EL of 15-years old German students?
- What is the relationship between EL and SEC of the students (such as type of books and number of musical instruments at home)?
- What is the relationship between the EL and TC (such as explanations, individualized help and the structure of lessons)?

RESEARCH METHODS AND DESIGN

This study used the paradigm of descriptive research, and the survey was used descriptively. In this study, the target population was 15-year-old German school students. Its sample consists of 6,504 students' PISA 2015 data obtained from the official PISA web site (http://www.pisa.oecd.org).

Data Analysis

This section consists of two parts. The first describes the development of the scales. The second explains the analyses used in this study. The EL and EO scales were developed in two stages, first exploratory and then confirmatory factor analysis. Two different scales were developed by the researchers because the Likert-type items for EO differ from other factors.

Developing the Scales

In the first part of the scale development, exploratory factor analysis with Statistical Package for the Social Sciences (SPSS) software (version SPSS 24) was used to examine the construct validity of the scale. In the second part, confirmatory factor analysis with Analysis of a Moment Structures (AMOS) software (version AMOS 18) revealed the relationships between the variables.

Exploratory Factor Analysis for Environmental Literacy

To determine whether or not to perform factor analysis, the Kaiser-Meyer-Olkin (KMO) Value and Bartlett's test of sphericity were calculated before the exploratory factor analysis (EFA). KMO values over 0.50 (KMO=0.90, $\rho<0.01$) indicate that factor analysis sampling was appropriate. Bartlett's test of sphericity was significant at (3,2061.74, $\rho <.01$), showing that the tool can be differentiated into factor structures. The t-test for the reliability of the meaningfulness of the median of top 27% and bottom 27% groups was done. The results are shown in Appendix 1, and the t-values are meaningful ($\rho < 0.01$). These results indicate that it is appropriate to perform a factor analysis.

As Appendix 2 shows, there are two important factors in the scale. While there are two factors in the graph with a high acceleration, the general trend of the graph in the third and subsequent factors are horizontal, and they have no significant declining trend. Thus, the contribution of the third and subsequent factors to the variance are very close to each other. According to EFA, it is seen that the 13-items were aggregated on the two factors, where eigenvalue is greater than 1 (Appendix 2). The Factor common variance, factor-1 load value and the analysis of converted basic components are shown in Table 1.

Table 1: Factor analysis of converted basic components

		Item	Factor Common Variance	Factor-1 Load Value	Analysis of converted basic components: Factor-1	Factor-2
Environmental Responsibility	1	How informed are you about this environmental issue? Air pollution	.67	.68	**.81**	
	2	How informed are you about this environmental issue? Extinction of plants and animals	.62	.66	**.78**	
	3	How informed are you about this environmental issue? The consequences of clearing forests\other land use	.63	.68	**.78**	
	4	How informed are you about this environmental issue? Water shortage	.56	.64	**.74**	
	5	How informed are you about this environmental issue? Nuclear waste	.54	.64	**.72**	
	6	How informed are you about this environmental issue? The increase of greenhouse gases in the atmosphere	.49	.64	**.67**	
	7	How informed are you about this environmental issue? The use of genetically modified organisms	.33	.56	**.52**	
Environmental Awareness	8	Identify the science question associated with the disposal of garbage.	.63	.62		**.78**
	9	Interpret the scientific information provided on the labelling of food items.	.60	.58		**.77**
	10	Predict how changes to an environment will affect the survival of certain species.	.56	.61		**.72**
	11	Recognize the science question that underlies a newspaper report on a health issue.	.53	.57		**.71**
	12	Identify the better of two explanations for the formation of acid rain	.15	.55		**.70**
	13	Describe the role of antibiotics in the treatment of disease.	.51	.57		**.69**
Explained Variance Total 55.2%, **Factor-1:** 29.2%, **Factor-2:** 25.9%, **Cronbach's alpha$_{EA}$**= .85, **Cronbach's alpha$_{ER}$**= .84						

According to the results of EFA, it was obtained that 13-items were loaded on the two factors labeled. Whole factors explained 55.2 % of the total variance. Through factor analysis, an attempt was made to bring together variables that measure the same structure with a small number of factors (Büyüköztürk, 2009). Item loads larger than 0.52 were chosen for inclusion in the scale. No items were excluded from the scale because they were not disassociated. As seen Table 1, the item loads for each factor were organized from the high value to low value as seen Table 1. Environmental Awareness (Factor-1) and Environmental Responsibility (Factor-2). The total variance was 55.2%. The variances of Environmental Awareness (EA) and Environmental Responsibility (ER) were found to be 29.2% and 25.9%, respectively. Analysis of Factors-1 and -2 found Cronbach's alpha internal consistency coefficients of 0.85 for EA and 0.84 for ER. As Appendix 3 shows, there seems to be a positive and meaningful relationship between EA, ER and EL (ρ <0.01).

Exploratory Factor Analysis for Environmental Optimism

A KMO value over 0.50 (KMO= 0.81, ρ <0.01) indicates that factor analysis sampling was appropriate. Bartlett's test of sphericity was significant at (8,370.62, ρ <.01), which shows that the tool can be differentiated into factor structures. The t-tests for the reliability of the meaningfulness of the median of top 27% and bottom 27% groups were done (Appendix 4). Appendix 4 shows that the t-values were meaningful (ρ < 0.01) except for item 5, which was excluded in the scale. According to the Eigenvalue, the number of important factors in the scale was one (Appendix 5). According to EFA, it was seen that the 6-items were made on the 1 factor, where eigenvalue is greater than 1 (Appendix 5). The Factor common variance, factor-1 load value and the analysis of converted basic components are shown in Table 2.

Table 2: Factor Analysis

		Item	Factor Common Variance	Factor-1 Load Value
Environmental Optimism	1	This issue will improve or get worse over next 20 years? Extinction of plants and animals	.49	.70
	2	This issue will improve or get worse over next 20 years? The increase of greenhouse gases in the atmosphere	.58	.76
	3	This issue will improve or get worse over next 20 years? Clearing of forests for other land use	.52	.72
	4	This issue will improve or get worse over next 20 years? Air pollution	.39	.62
	5	This issue will improve or get worse over next 20 years? The use of genetically modified organisms	.49	.70
	6	This issue will improve or get worse over next 20 years? Nuclear waste	.30	.55
		Explained Variance Total 45.9%, **Cronbach's alpha** .77		

According to result of EFA, it is obtained that 6 items were loaded on the Factor-1 labeled. Whole factors explained 45.9 % of the total variance. Those item loads larger than 0.55 were chosen and included in the scale. No items were excluded from the scale because they were not disassociated. The Cronbach's alpha internal consistency coefficient was 0.77 for Factor-1.

Confirmatory Factor Analysis for EL and EO

Structural validity was tested by confirmatory factor analysis as described above. The initial results obtained by confirmatory factor analysis indicated that some of the values were not within the acceptable limits. For this reason, covariance was created between the error terms of the items within each latent variable in the model. These findings are shown in Table 3.

Each correction should be based on a theoretical basis (Meydan and Sesen, 2015; Karagoz, 2016). Therefore, the error terms of the items in each factor were associated (Karagoz, 2016). Then, confirmatory factor analysis was performed again. Corrected confirmatory factor analysis seems to have good fit in general. Good fit and acceptable fit have different value ranges. Furthermore, it is possible that a model may fit the data, although one or more fit measures may suggest bad fit (Schermelleh-Engel, Moosbrugger, & Müler, 2003).

Table 3: Fit Criteria (Schermelleh-Engel, Moosbrugger, & Müler, 2003) and Model Fit Measures

	Good Fit	**Acceptable Fit**	**EL Model Fit**	**EO Model Fit**
c2/sd	$0 \leq c^2/sd \leq 2$	$2 \leq c^2/sd \leq 3$	8.83	28.22
ρ	$0.05 \leq \rho \leq 1$	$0.01 \leq \rho \leq 0.05$	.00	.00
Root Mean Square Error of Approximation	0≤RMSEA≤0.05	0.05≤RMSEA≤0.08	.04	.07
Normed Fit Index	0.95≤NFI≤1.00	0.90≤NFI≤0.95	.99	.99
Tucker-Lewis Index	0.95≤TLI≤1.00	0.90≤TLII≤0.95	.98	.95
Comparative Fit Index	0.97≤CFI≤1.00	0.95≤CFI≤0.97	.99	.99
Relative Fit Index	0.90<RFI<1.00	0.85<RFI<0.90	.98	.95

As Table 3 shows, the significance value was found to be .00. Moreover, the ρ-values and most of the other values may be interpreted as indicating good fit.

FINDINGS

In this section, the findings are reported for the research questions. The results of the analysis are displayed in the tables according to whether they are statistically significant or not. Cohen’s d (for t-test) and Cohen’s f (for ANOVA) effect sizes were used to calculate effect size. The findings are discussed in three sections: factors in EL, SEC and TC that influence EL.

Findings about the Factors in Environmental Literacy

In this research, exploratory and confirmatory analyses were used to evaluate the data derived from the analysis of quantitative data. As Appendix 6 shows, the students had high EO (X=3.28/4.00), while EA (X=2.86/4.00) and ER (X=2.28/4.00) and were low. Appendix 7 shows that there seems to be a positive and meaningful relationship between EL and EO at a low level ($r=0.16$, $\rho <.01$). As Appendix 8 shows there was a positive correlation between the EL of students and EA, ER and EO. An increase in one of these three factors affects EL positively.

As appendix 9 shows, when the factors related to the EO of the German students were examined, the factor of the extinction of plants and animals with a coefficient of 1.67 had the highest factor value in PISA 2015. The students seemed to perceive EO as air pollution, clearing forests, and greenhouse gases. The last item is GMO with a coefficient of 1.00. Moreover, this research shows that students should be more informed and encouraged to take responsibility for environmental issues, particularly GMO and water shortages.

Findings about the SEC that influence EL

This section includes analyses of the students' SEC. Parametric tests, ANOVA, and the t-test were used to evaluate the data derived from the analysis of quantitative data.

Table 4: The results of the t-test for EL and type of books at home

Type of Books	Answer	N	$\bar{X}$	sd	Df	t	ρ	η^2
Classic Literature	Yes	2,363	2.59	.27	5,500	3.86	.00	0,03
	No	3,139	2.56	.29				
Poetry	Yes	2,952	2.58	.28	5,554	2.06	.04	0,02
	No	2,604	2.56	.29				
Books on Art, Music or Design (BAMD)	Yes	2,928	2.59	.28	5,544	3.31	.00	0,03
	No	2,618	2.56	.28				
Books to help with school work (BHSW)	Yes	4,943	2.58	.28	5,621	1.35	.18	0,02
	No	680	2.56	.28				

There was significant relationship between both classic literature and books on art, music, or design that students have at home and EL ($t_{Classic\ Literature}$ (5,500) =3.86. $t_{Art,\ Music\ or\ Design}$ (5,544) =3.31, $\rho < .01$). However, there was no significant relationship between both books of poetry and books to help with school work that students have at home and EL (t_{Poetry} (5,554) =2.06, $t_{School\ Work}$ (5,621) =1.35, $\rho > .01$). Those who have these types of books at ($X_{Classic\ L.}$=2.59, X_{Poetry} = 2.58, X_{BAMD}= 2.59, X_{BHSW} = 2.58) home had a higher average EL than those who did not ($X_{Classic\ L.}$=2.56, X_{Poetry} = 2.56, X_{BAMD}= 2.56, X_{BHSW} = 2.56).

Table 5: The results of ANOVA for EL and number of musical instruments at home

Musical Instruments	N	$\bar{X}$	Source of Variance	Df	Mean Square	F	ρ	Sig. Dif.	η^2
None (a)	1,725	2.56	Between groups	3	.59	7.43	.00	d-a, d-b	0,06
1 (b)	1,379	2.56	With-in group	5,669	.08				
2 (c)	1,050	2.58	Total	5,672					
3 and more (d)	1,519	2.60							

There was a meaningful relationship between EL and number of musical instruments at home (F (3, 5,669) =7.43, ρ <.01). According to the results of the Scheffe test, the EL of students who had 3 or more musical instruments (d) (X=2.60) were more positive than those who had only a single musical instrument (b) (X=2.56) and those who had none (a) (X=2.56).

Table 6: The results of the t-test for EL and SEC

SEC	Responses	N	$\bar{X}$	Sd	Df	t	ρ	η^2
Number of books at home	0-25	1,326	2.53	.31	5,673	5.55	.00	0,18
	More than 25	4,349	2.58	.27				

As Table 6 shows, there was a meaningful relationship between EL and SEC (t (5,673) =5.55, ρ <.01). Students' SEC affect their EL. Thus, it can be said that as the SEC increases, EL increases. These results show that SEC has a large effect on the EL (η^2 = 0.18).

Findings about the Teaching Characteristics that influence EL

This section includes analyses of TC. ANOVA was used to evaluate the data derived from the analysis of quantitative data.

Table 7: The results of ANOVA according to EL and frequency of adapting lessons

Adapting Lessons	N	$\bar{X}$	Source of Variance	df	Mean square	F	ρ	Sig. dif.	$η^2$
Never or almost never (a)	795	2.55	Between groups	3	.75	7.18	.00	d-a, d-b, c-a, c-b	0,07
Some lessons (b)	1,548	2.55	With-in group	4,120	.11				
Many lessons (c)	1,175	2.59	Total	4,123					
Every lesson or almost every lesson (d)	606	2.61							

As Table 7 shows, there is a meaningful relationship between EL and teachers' frequency of adapting the lesson to class needs and knowledge (F (3, 4,120) =7.18, ρ <.01). According to the results of the Scheffe test, students' EL was higher for students whose teachers adapted lessons to their needs in every lesson or almost every lesson by the teacher (d) (X=2.61) and lower for those whose lessons were adapted sometimes (b) (X=2.55), or never or almost never (a) (X=2.55).

Table 8: The results of ANOVA for EL and the frequency of teachers' providing individual help

Individual Help	N	$\bar{X}$	Source of Variance	df	Mean square	F	ρ	Sig. dif.	$η^2$
Never or almost never (a)	1,106	2.57	Between groups	3	.53	5.08	.00	d-a, d-b	0,06
Some lessons (b)	1,603	2.55	With-in group	4,091	.11				
Many lessons (c)	986	2.58	Total	4,094					
Every lesson or almost every lesson (d)	400	2.62							

As Table 8 shows, there is a meaningful relationship between EL and the frequency of teachers providing individual help when students had difficulties ($F(3, 4{,}091)=5.08$, $\rho <.01$). According to the results of the Scheffe test, the EL of the students who were provided individual help in every lesson or almost every lesson (d) ($\bar{X}=2.62$) was higher positive than that of those who did so sometimes (b) ($\bar{X}=2.55$), or never or almost never (a) ($\bar{X}=2.57$).

Table 9: The results of ANOVA for EL and the frequency of teachers' explanations of scientific ideas

Explanations of Scientific Ideas	**N**	$\bar{X}$	**Source of Variance**	**df**	**Mean square**	**F**	**ρ**	**Sig. dif.**	η^2
Never or almost never (a)	550	2.52	Between groups	3	1.10	10.91	.00	d-a, d-b, c-a, c-b	0,09
Some lessons (b)	1,573	2.56	With-in group	4,227	.100				
any lessons (c)	1,373	2.59	Total	4,230					
Every lesson or almost every lesson (d)	735	2.60							

As Table 9 shows, there is a meaningful significant relationship between EL and frequency of teachers explanations of scientific ideas ($F(3, 4{,}227)=10.91$, $p<.01$). According to the results of the Scheffe test, the EL of the students whose teachers explained scientific ideas in every lesson or almost every lesson (d) ($\bar{X}=2.60$) were higher than those who did so sometimes (b) ($\bar{X}=2.59$), or never or almost never (a) ($\bar{X}=2.52$).

Table 10: The results of ANOVA according to EL and frequency of teachers' continuing to lecture

Teachers' Continuing to Lecture	N	$\bar{X}$	Source of Variance	df	Mean square	F	ρ	Sig. dif.	η^2
Never or hardly ever (a)	607	2.58	Between groups	3	.095	.98	**.40**	-	0,02
Some lessons (b)	1,134	2.57	With-in group	4,447	.097				
Most lessons (c)	1,360	2.56	Total	4,450					
Every lesson or almost every lesson (d)	1,350	2.58							

As Table 10 shows, there is no significant relationship between EL and frequency of teachers continuing to lecture (F(3, 4,227)=.98, ρ >.01). Accordingly, it can be said that as the frequency of teachers continuing to lecture increases, EL does not increase.

Table 11: The results of ANOVA for EL and frequency of changing the structure of lessons to suit class needs

Changing the Structure of Lessons	N	$\bar{X}$	Source of Variance	df	Mean square	F	ρ	Sig. dif.	η^2
Never or almost never (a)	1,337	2.56	Between groups	3	.498	4.72	.00	d-b	0,06
Some lessons (b)	1,433	2.55	With-in group	4,078	.105				
Many lessons (c)	925	2.59	Total	4,081					
Every lesson or almost every lesson (d)	387	2.61							

As Table 11 shows, there is a meaningful relationship between EL and frequency of teacher changing the structure of lessons to suit class needs (F(3, 4,078)=4.72, ρ <.01). According to the results of the Scheffe test, the EL of the students whose teachers changed the structure of lessons to suit class needs every lesson or almost every lesson (d) ($X=2.61$) were higher than that of those whose teachers did so sometimes (b) ($X=2.55$).

CONCLUSION AND DISCUSSION

In this research, parametric tests, ANOVA, and the t-tests were used to evaluate the data derived from the analysis of quantitative data. In this section, the data obtained are discussed in two parts: SEC and TC that influence EL.

Conclusion and discussion about SEC that influence EL

This study showed there was a significant relationship between EL and the number of musical instruments and books at home (SEC). Oral and McGivney (2013) mention that one of the factors thought to affect student achievement is having books at home. Other similar studies have found that books have positive effects on scientific literacy (Ozer and Anil, 2011; Kaya and Dogan, 2016) and mathematics literacy (Ozer and Anil, 2011). In addition, this study showed there was a significant relationship between both classic literature and books on art, music, or design that students had at home and EL. On the other hand, this study highlighted that there was no significant relationship between both books of poetry and books to help with school work at home. Furthermore, classic literature and books on art, music, or design that students had at home had greater positive effects on EL. Ozer and Anil (2011) claim that there is a relationship between scientific literacy and educational materials that students have at home, but no relationship between mathematics literacy and educational materials. It can be stated that having books to help with school work at home does not affect EL since education is not examination-oriented in Germany. Furthermore, as reported by Abdu-Raheem (2015), there is a relationship between the academic performance of students and the SEC of their families. This research also showed that there was a significant relationship between EL and SEC. A similar finding was mentioned by Erbas, Teksoz and Tekkaya (2012). Turkish students' responsibility towards the environment varies by SEC. In a similar vein, Lin and Shi (2014) mention that economic, social, and cultural status, internal student factors, seem to affect certain aspects of EL. This study found that students' SEC affected their EL, and as SEC increase, EL increases. Studies have indicated that SEC as a significant effect (Hattie, 2003) and its importance for teaching (Lotz and Lipowsky, 2015). Lotz and Lipowssky (2015) in an updated study of Hattie's (2003) study, found the effect size between student achievement and SEC (such as family resources) was d = 0.52. Consequently, these results show that SEC is effective in both student achievement and environmental literacy.

Conclusion and Discussion about Teaching Characteristics that influence EL

The link between students and teachers is important to the attainment of educational goals (Nembhard, 2005). An important part of the responsibility for strengthening this bond belongs to teachers. For this reason, raising the educational standards of teachers, who are schools' most important resource, is critical (OECD, 2009b). The instructional quality of the teacher has a powerful effect on achievement (Hattie, 2003). In particular, the teaching process should be supported in order to improve the quality of education. Thus, educators are exploring ways to create schools that improve the learning and performance of students in many parts of the world (Whole Schooling Research Project, 2000). As Katsara (2015) claims "The role of the teacher is to facilitate the learning process" (p.12). The character of a teacher is also significant for effective teaching practices in enriched learning environments (Pennock and Moyers, 2012). This study's results provided evidence that there was a significant relationship between teachers adapting lessons to their students' needs and knowledge, changing the structure of their lessons, providing individual help when students have difficulties, explaining science ideas in every lesson and EL. In fact, research has identified these characteristics as effective teacher skills. Sprague (2012) stated about effective teachers "They can adapt or differentiate instruction for all students by using some basic problem-solving techniques that involve quickly identifying issues, generating alternative solutions and trying one or two to see if they work" (p. 3).

On the other hand, this study's findings suggest that there was no meaningful relationship between teachers continuing to lecture in their science lessons and EL. The reason for this may be that students want a student-centered learning environment instead of a teacher-centered learning environment. In addition, various approaches can be used for student-centered learning, including case-based learning, project-based learning, and problem-based learning (Pederson and Liu, 2003). These environments focus on meaning formation, inquiry and authentic activity, unlike traditional teaching (Garrett, 2008). These environments acknowledge each student can learn, research and analyze current knowledge in a different way (Attard, Di loio, Geven, and Santa, 2010).

Ultimately, individual support given by teachers has a positive effect on EL. For this reason, teachers should create atmospheres where students are supported. Although lecturing does not affect EL, teachers' explanations of scientific ideas in science lessons increase EL.

Adapting all lessons to the needs of the students and changing the structure of lessons accordingly can help students to increase their EL.

DIDACTICAL RECOMMENDATIONS

According to the results, it might be concluded that the environmental literate individual needs awareness and responsibility towards the environment, as well as, to be optimistic towards the environment. Because, the relationship between EL and both ER and EA is positive and meaningful. Therefore, the knowledge and awareness levels of students should be increased in order to educate more environmentally literate individuals. The relationship between EL and EO is also positive and meaningful. However, it is also apparent that they are more concerned about environmental issues. Therefore, they should be encouraged to increase their knowledge and awareness about the environment as well as to develop positive emotions towards the environment to remove or reduce environmental concerns. Increasing their optimism about the environment will contribute to higher EL.

States and schools should be aware of the effect of SEC on EL. Governments should provide books to students of low socioeconomic status. Science teachers should also be aware of the effect of SEC on EL, and enrich the teaching methods and materials used in their lessons. For instance, the use of musical instruments by science teachers during EE may increase EL levels.

Furthermore, the teaching profession starts with pre-service training and continues with in-service training (Kaya and Gödek, 2016; Kaya, 2011). Therefore, teacher training and practices should be developed to teach environmental issues in teacher education. In career teachers also should be supported by in-service teacher education.

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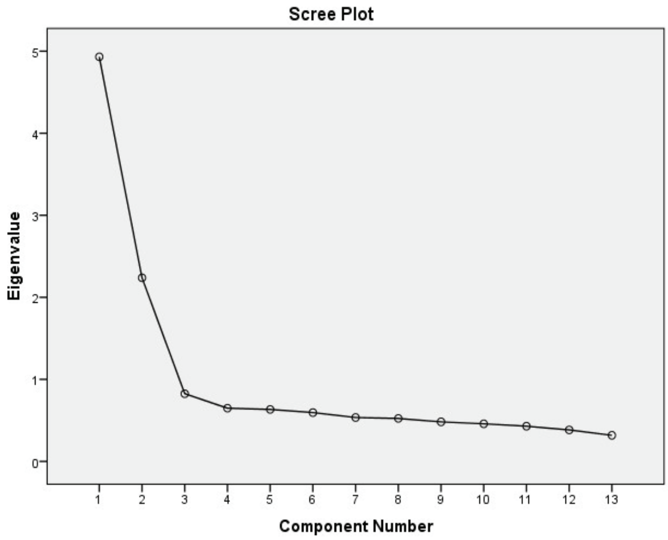
Appendixes

Appendix 1: Analyses of Item for EL Scale

Item	**T (Bottom%27-top%27)[1]**
1	25,37**
2	20,14**
3	29,57**
4	30,63**
5	31,56**
6	30,69**
7	30,54**
8	16,22**
9	16,21**
10	17,71**
11	14,18**
12	20,17**
13	18,18**

[1] $n_1 = n_2 = 1.756$, N of Items =13, $^{**}p < .01$

Appendix 2: Graphic of Eigenvalues for EL Scale



Appendix 3: Correlation between EL and EO

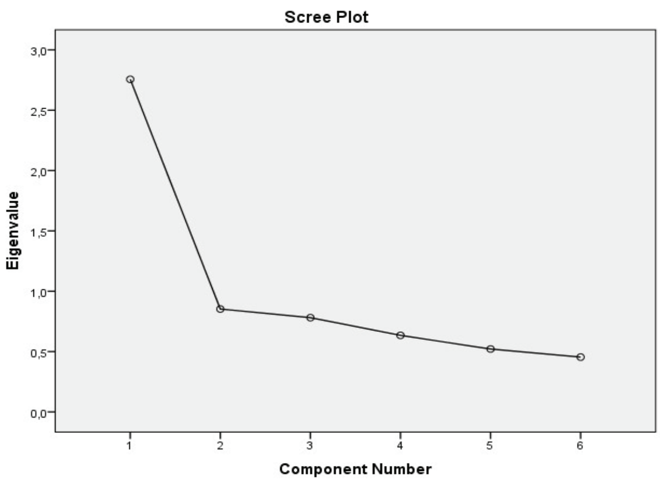
		EA	ER	EL
	R	1		
EA	P			
	N	6504		
	R	-,38**	1	
ER	P	,00		
	N	6504	6504	
	R	,67**	,43**	1
EL	P	,00	,00	
	N	6504	6504	6504

Appendix 4: Analyses of Item

Item	t (Bottom%27-top%27)[1]
1	5,00**
2	4,55**
3	4,80**
4	7,45**
5	,82
6	4,30**
7	2,5**

[1] $n_1 = n_2 = 1.756$, N of Items =13, $^{**}p < .01$

Appendix 5: Graphic of Eigenvalues



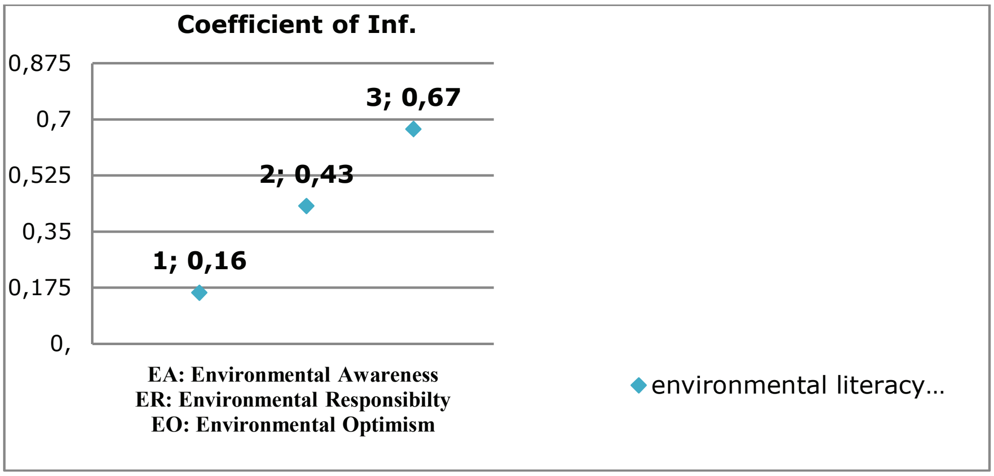
Appendix 6: Mean of Factors

	EA	ER	EL	E0
Mean	2,86	2,28	2,57	2,46 (3,28/ 4.00)
Maximum Value	1,00	1,00	1,00	1,00
Minimum Value	4,00	4,00	4,00	3,00

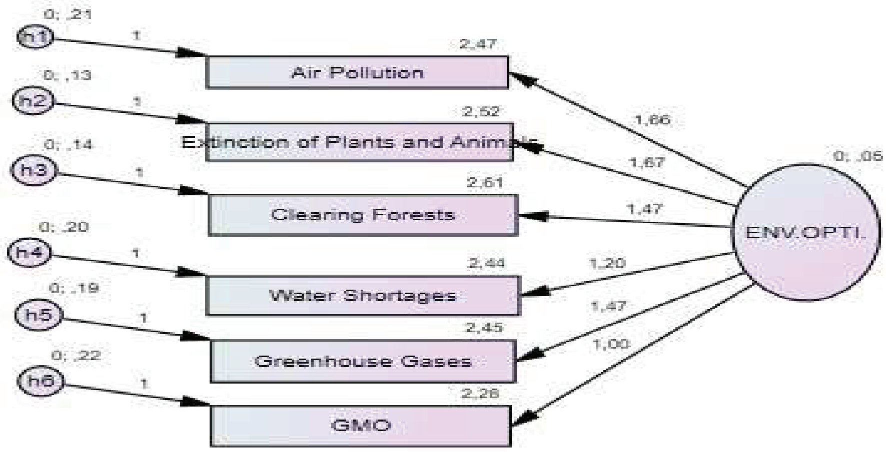
Appendix 7: Correlation between EL and EO

		EL	EO
	R		
EL	P		
	N		
	R	,16**	1
EO	P	,00	
	N	6504	6504

Appendix 8: Correlation coefficients



Appendix 9: Views on EO



2.1.1.2. Change in the Environmental Literacy of German Students in Science Education between 2006 and 2015

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Abstract

This empirical study intends to present core results of the change in environmental literacy of German students by analysing PISA 2006and 2015 data. The study is carried out within the scope of environmental literacy in science education. The data are based on findings of both PISA 2006 data (N= 4891) and PISA 2015 data (N= 6504) of German students which were published in the official PISA site (http://www.pisa.oecd.org). In this study, a valid and a reliable 'environmental literacy' scale is developed. In addition, students' attitudes towards science affecting their environmental literacy are compared between 2006 and 2015. The study is conducted based on the paradigm of a descriptive field study survey. The validity and reliability of the 'environmental literacy' scale is tested in two stages by applying exploratory factor analysis with SPSS and confirmatory factor analysis with AMOS. In addition, parametric tests (ANOVA) and correlation are used to assess the data obtained from the analysis of quantitative data. The findings demonstrate a positive and meaningful relationship between 'environmental literacy' and the sub-factors (Environmental Awareness (EA), Environmental Responsibility (ER), and Development of Environmental Behavior (DEB)) (r_{EA} = 0.73, r_{ER} = 0.43, r_{DEP}= 0,37, $p < .01$). Moreover, there is an increase in the mean of the environmental literacy ($\square_{2006}$ = 2,55; $\square_{2015}$ = 2,58). According to the results, the major of students (63 % and over) indicate that 'they can describe the role of antibiotics in the treatment of disease' and 'they can predict how changes to an environment will affect the survival of certain species' easily on their own in both 2006 and 2015. However, approximately 20 % of German students point out that they cannot recognize the science question that underlies a newspaper report on a health issue' on their own. In addition, the majority of German students (80 %) point out that they have information about the consequences of clearing forests for other land use in 2006 and 2015. On the other hand, more than 60 % of German students think that they do not have sufficient knowledge about the use of GMO in 2006 and 2015. In the light of the results of this study some suggestions related to environmental issues for the development of science curricula are discussed. For instance, one of the suggestions is that the subject of genetically modified organisms and health issue should be more comprehensive in the German science curricula. In addition, critical reflection and decision making about science issues is important to educate an environmental literate citizen.

Keywords: Science Education, Environmental Literacy, PISA

Introduction

In 2005, UNESCO launched its Decade of Education for Sustainable Development (2005-2014), a project by which educational institutes around the world would focus on educating more qualified individuals for a more sustainable future (Kaya and Elster, 2017). It is critical for the enhancement of the quality of future SE, especially environment education, that researchers bring to light the outcome of this educational project. One of the main purposes of this study is to present the results of the changes in environmental literacy (EL) of German students before and after implementation of this education by analysing PISA 2006 and 2015 data.

Another main purpose is to develop a model for assessing EL directly by using PISA data. It has been reported that PISA will be expanded in the scope of measurement coverage after the PISA 2015 evaluation (TEDMEM, 2017). It is the belief of the researchers that the present study will have a positive effect on this expansion, because, as Kaya and Elster (2017) mentioned, not enough research has been conducted on EL using PISA data, and although scientific literacy tasks in PISA include items related to environmental issues, it does not measure the score of EL directly.

The purpose of this research is to determine the change in the EL of German pupils from 2006 to 2015. Within the scope of this research, the development of environmental issues based on the PISA data is first presented. Next, before defining the research questions, the theoretical framework of literacy, especially science and EL, is introduced in order to reveal the importance of the research.

How is Environmental Education Linked to PISA?

International organizations have reported on the development of EE from past to present by organizing conferences or/and meetings on EE (The Belgrade Charter, 1972; WCED, 1987; UNESCO-UNEP, 1976, 1978; UNCED, 1992; UNESCO, 1997; United Nation, 2002). Environmental studies and sciences programs were first established in the 1970s and gave rise to the increase of public awareness on environmental studies and issues (Coppola, 1999). In 1972, EE gained international acclaim with the Stockholm Declaration (Belgrade Charter, 1975; Wright, 2002). In the report of the Belgrade Charter (1975), it was explained that the six frameworks of EE are awareness, knowledge, attitude, skills, evaluation ability and participation. Similarly, the Tbilisi Declaration reported that there are four objectives: awareness, knowledge, attitudes, skills, and participation in EE (UNESCO, 1978).

At the beginning of the 1980s, the first EE curriculum, named "Procedures for Developing an EE Curriculum", was published under the auspices of UNESCO-UNEP, and then revised in the mid-1980s (UNESCO-UNEP, 1994). In 1987, The Brundtland Report, also known as the Common Future, was published by the World Commission on Environment and Development. This report outlines the concept of sustainable development, which is seen as an interrelation of the concepts of environmental protection and economic growth (McCrea, 2006). The transition from the concept of EE to the concept of sustainable development began after it was highlighted at the international conference in Thessaloniki on

Environment and Society: Education and public awareness for sustainability hosted by UNESCO in 1997 (Pavlova, 2011).

In 1997, the OECD Programme for International Student Assessment (PISA) was created by OECD member countries (OECD, 2013a), and the first PISA survey was launched in 2000 (OECD, 2000), which involves PISA assessing students every three years in three subjects (science, reading and mathematics literacy) (MoNE, 2010). Most of the countries make certain that the PISA assessment tools are internationally accepted and take into consideration the culture and curriculum of the participating countries and their economies (OECD, 2016b). The latest PISA assessment in 2015 was centred on SL, an area that has continued to play an increasing role in our economic and social lives (OECD, 2016a). The international organization, UNESCO, has been very active, from past to present, in the development of EE and will continue to support this education in the future. The educational outcomes from international assessments, especially the PISA, are important insofar as they serve to maintain the quality of this development.

What is Literacy?

Literacy is a basic element of the right to education, as recognised by the Universal Declaration of Human Rights (UNESCO, 2013a). Despite there being general agreement that literacy is a human right (Keefe and Copeland, 2011), a common definition, accepted by everyone, is still lacking, as discussed in the previous section. Moreover, the idea of literacy has evolved in line with changes in cultural communicative practices and technological developments (Fellowes and Oakley, 2014). As a result, its usage has significantly expanded up to today (McBride, Brewer, Berkowitz, & Borrie, 2013). In recent years, the scope of its definition has grown to include many areas of interest, such as SL and EL (Monseley, 2000; Ozturk, Tuzun & Teksoz, 2013).

However, following the start of the Industrial Revolution, the concept of literacy began to be associated with the ability to read and write (Roth, 1992; Coppola, 1999; Monseley, 2000; Daley, 2003; Cambridge Assessment, 2013; McBride, Brewer, Berkowitz, & Borrie, 2013). UNESCO has had a significant role in developing literacy among its member states ever since the middle of the 20th century, and its definition of literacy has evolved substantially over time (Newman and Beverstock, 1990). In 1951, literacy was defined by UNESCO as the capability of a person to read, write, and fully comprehend a brief and uncomplicated expression in daily life (Newman and Beverstock, 1990: 45). Similarly, an alternative definition of literacy is the skill of individuals to get involved in the activities that need literacy to maintain the efficient functions of the society they live in, and to read, write and calculate for both personal and social development (UNESCO, 1978). In this sense, literacy provides a foundation for many other learning opportunities (UNESCO, 2013a), with the reason being that the innovative concept of “literacy” is concerned with the capacity of students to analyse, reason and communicate effectively as they pose, solve and interpret problems in a variety of subject matter areas. (PISA, 2005). It is anticipated that in time to come this innovative concept of literacy will move beyond the skill of reading and writing and be rather described as the ability to transform knowledge into practice.

Framework for Scientific/Science Literacy

Science is very significant for individuals if they are to make sense of their lives (Godek, 2002). Ultimately, individuals have the desire to make daily natural events more understandable and useful for them (Agin, 1974). The needs of individuals are therefore never-ending and continuous (Kalkandelen, 1979). In today's world, education, especially Science Education (Agin, 1974) is a key to transforming individuals into scientifically literate persons. Scientific literacy has thus become a concept common to the basic goals of Science Eduaction (Gabel, 1976). Moreover, scientific literacy has become the basis on which individuals can fully participate in society (Bybee, 2008). Through SE and the SL that results from it, individuals gain the ability to engage with science-related issues and scientific ideas (PISA, 2013b).

In light of the descriptions of literacy, SL is defined as the ability to read, comprehend, and discuss scientific matters intelligently (Shamos, 1988). In other words, it describes the ability of a person to understand scientific laws, theories, phenomena and objects and to be equipped with the necessary base of scientific knowledge to make informed decisions for their life (Dragoş and Mih, 2015). Although scientists, educators, and philosophers of science have their own definitions of what it means to be scientifically literate, it should not be ignored that this concept is constantly evolving (Gabel, 1976). In these respects, Shen (1975 as cited in Liu, 2009) described six components of SL: (a) understanding basic science concepts, (b) understanding the nature of science, (c) understanding the ethics guiding scientists' work, (d) understanding interrelationships between science and society, (e) understanding interrelationships between science and humanities, and (f) understanding the relationships and differences between science and technology. In contrast, according to the Board on SE

(2016), there are three elements of SL, namely, an understanding of scientific practices, content knowledge and an understanding of science. These two alternative definitions serve to demonstrate, in short, that, just as is the case for the definition of SL, there is no common view on the categories delimiting the concept of SL.

In general, it can be said that scientific literacy means to have an appreciation of the basic principles of science and an understanding of what scientific research produces (Smithsonian Institution, 2011). Individuals should have some understanding of or familiarity with the social processes that accompany most environmental issues and how scientific methods work (Schneider, 1997). A scientifically literate citizen must therefore have an understanding of how the scientific and decision-making elements interact (Schneider, 1997). In support of this, Hurd (1998) mentioned that a literate person uses science knowledge where appropriate in making life and social decisions, forming judgements, resolving problems, and taking action. Although the major advantage of being endowed with SL is that it provides a basis, at the school level, of the intentions of SE (Holbrook and Rannikmae, 2009), it entails much more than simply knowing the basic facts established by science (Board on SE, 2016). In summary, a definite answer to the question of 'what is SL?' should not be sought. Instead, we should seek to find answers to the questions of 'what is the scope of SL? and How can we meet the expectations of societies in the future within that scope?'. In this way, we can train qualified science literate individuals, accordingly.

Change in Science Literacy in PISA

The concept of SL is constantly being updated by PISA. In 2000, PISA defined scientific literacy as the capability of using scientific information, asking questions and making conclusions based on proof for the purpose of comprehending the natural world, making determinations about it and interacting with it. In 2006 and 2009, PISA redefined SL as follows (OECD, 2006: 12; OECD 2009: 128): the holding and use of scientific information to make new questions, draw new pieces of information, make sense of the phenomena related to science, and reach conclusions related to scientific issues based on proof; also the ability to access the core of unique aspects of science by regarding it as a type of human information and investigation, being conscious about the ways that science and advanced technology determine our living situations, in material, intellectual and cultural terms, and being eager to get involved in scientific subjects, as well as having personal opinions about science as a requirement of being a contemplative citizen. In 2015, SL was defined by OECD (2013b: 7) as the skill to question and discuss scientific matters and people's opinions related to science, a requirement to being a meditative citizen. These regular updates to the concept of SL by PISA are made according to the changing conditions of society.

Framing the Concept of Environmental Literacy (EL)

In 1968 Roth (1968, as cited in Roth, 1992), indicated that the concept of EL was first revealed in an academic paper. In the 1990s, however, the field of EE underwent a maturation period within the framework of formulating the concept of EL (McBeth and Volk, 2010). EE programs are designed to raise and nurture the development of EL throughout the lifetime of the human (Subbarini, 1998). Moreover, the main aim of EE continues to be the development of EL, and ultimately behavioural change in terms of making informed decisions related to natural resource management (Bennett and Roth, 2015). As NAAEE informs us, EL includes dispositions, knowledge, and competencies applied for the purpose of responsible environmental behaviour (Daniš, 2013).

However, as stated earlier, there is no universally accepted definition of literacy (Keefe and Copeland, 2011), especially SL (DeBoer, 2000) and EL (Loubser, Swanepoel & Chacko, 2001; Morrone, Mancl & Carr, 2001). Despite the fact that the concept of EL has been in use for many years, coming up with a comprehensive description of it continues to be challenging due to its complexity. EL is still highly valued in SE, as it has allowed for many solutions related to environmental problems in science to be found. It is because of this that so many researchers have attempted to classify EL.

Researchers have argued that EL has to accord with the five categories of EE concepts (awareness, knowledge, attitude, skills, and participation) in order for it to develop into positive environmental behaviours (Wisconsin Department of Public Administration, 1991). In the study by Roth (1992), six major areas of EL were proposed: environmental sensitivity, knowledge, skills, attitudes and values, personal investment and responsibility, and active involvement. Many researchers have sought to provide a working definition of EL, such as the one offered by Subbarini (1998: pp. 245), which states that EL requires individuals to be able to convey and make use of the main ecological concepts and rules, make sense, on ecological grounds, of the effect of human activities on the environment, determine and do research about environment-related matters to come up with different solutions, and assert the values related to the environment that encourage the use of natural resources in a sensible and responsible manner; or the one put out by the DC Environmental Literacy Workgroup (2012), stating “Environmental literacy is the development of knowledge, attitudes, and skills necessary to make informed decisions concerning the relationships among natural and urban systems”.

An examination of the literature showed that there are three levels of EL: nominal, functional and operational (Chacko, 1998). According to Chacko (1998), a person who has nominal EL has the ability to recognize many of the basic terms used in discussing the environment, a person who has functional EL has a broader range of knowledge and understanding about the nature and interaction of human social systems and other natural systems, and a person who has operational EL has progressed beyond functional literacy in both the breadth and depth of understandings and skills.

Literacy, especially EL, is not a process of indoctrination of any one agenda, but rather a building of knowledge and experiences to help persons make informed decisions (TAEE, 2013). Environmentally literate people are equipped with more than just knowledge about ecology; completely literate individuals combine knowledge with values, which leads to action (Morrone, Mancl & Carr, 2001). Moreover, environmentally literate individuals are capable of individually and collectively making informed decisions concerning the environment, are willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment, and are actively engaged in social life

(NAAEE, 2011). In short, EL involves the ability to adapt to changes in environmental resources and systems, and their dynamics (Scholz, 2011).

Ultimately, studies have shown that the two general concepts of science and EE and science and EL are related to each other; that is, EE is a prerequisite for qualified SL (O'Hearn, 1972). In viewing this relationship as such, it is possible to see how the problems related to EE can be overcome (Longbrake, 1974). The influence of these interrelated and interdependent concepts should be a reflection of the impact of SE on the quality of the education.

Research Questions

To be consistent with the PISA definition of scientific literacy, assessment items are required to be designed via the application of scientific knowledge and through the demonstration of the scientific competencies within certain contexts, such as environmental issues. Although PISA was not designed specifically to assess environmental science, by taking the questions used in the PISA science assessment, it was determined that some were related to environmental science (Erbaş, Tuncer Teksöz & Tekkaya, 2012). Furthermore, while PISA assesses reading, science, and mathematics literacy every three years, EL is not directly assessed, although some of the items do fall within an environmental context. As it has been argued that not enough research on EL has been conducted using PISA data (Kaya and Elster, 2017), this study seeks to do research on EL by using PISA data from 2006 to 2015. In conducting this research, the main aim was to determine the change in the EL of German pupils from 2006 to 2015. More specifically, the research questions investigated in this study were:

- What factors influence EL?
- In what way do the EL factors (development of environmental behaviour, environmental awareness and environmental responsibility) change from 2006 and 2015?
- How does the change in the influence of students' attitudes towards science (such as enjoyment of science, interest in science) impact EL from 2006 to 2015?
- What changes occur from 2006 to 2015 in the influence of teaching methods for lessons on EL?

Research Methods and Design

In this section, we present the 'type of study', 'the sampling and data collection', and the analysis of data.

Type of study

For this field study, descriptive research methods were employed. The basic aim of descriptive analysis is to provide the reader with the ability to summarize and interpret the findings (Yıldırım and Simsek, 2003). Specifically, a survey format was used in the context of the method of description for this research. Surveys, which are used to determine the current situation, have the advantage of allowing more quantitative data to be gathered (Cepni, 2007). Questions related to the environmental issues in the PISA 2015 student questionnaire were included in this study. In the context of this study, the questionnaire was used with structural equation modelling to examine the factors affecting German students' development of environmental behaviour (DEB), environmental responsibility (ER) and awareness (EA).

Sampling and data collection

In this study, the sample population was restricted to 15-year-old German students who were attending school in either 2006 or 2015. The PISA sample selection was conducted randomly by applying the two-stage stratified sampling method (Albayrak Sarı, 2015). The study sample included 4891 pupils from 2006 and 6504 pupils from 2015, determined using PISA data from both 2006 and 2015. The data were obtained via the internet from the official PISA website (http://www.pisa.oecd.org). In this study, the data obtained with the participation of students from Germany involved PISA data from 2006 and 2015.

Analyses of data

This section consists of two parts, with the first part describing how the scale was developed, and the second part explaining the analysis used in this study. The Environmental Literacy scale was developed in two stages: exploratory and confirmatory factor analysis stages.

Theoretical framework of scale

In PISA 2006, approximately 33 percent of the context included resources and environments (Bybee, 2008), while in PISA 2015, approximately 11% of the context included environmental issues, and the number of items were found to have decreased compared to 2006-PISA. According to PISA results, the definition of EL includes environmental awareness and environmental responsibility (Kaya and Elster, 2017). When the theoretical framework of EL is examined (Figure 1), EL includes environmental behaviours. According to the scope of EL, as shown in Figure 1, the EL scale was developed using common items related to environmental issues from both 2006 and 2015. Moreover, two of the three sub-factors, namely environmental awareness and environmental responsibility, were included in the PISA data. However, the "Development of Environmental Behaviour (DEB)", a new factor, was added to the scale of EL. DEB is used to determine whether the students in the school are given responsibilities to improve their skills in demonstrating environmental behaviours.

Scholz (2011) argues that 'environment' must be redefined as a co-evolving system coupled to a human system. Thus, in line with this view, he recommends that future research should be designed on the basis of human and environment systems, and he linked trans-disciplinary and disciplined interdisciplinary to the concept of EL. In this respect, the focus points are the interaction of human systems and environmental systems, how individuals learn from feedback and can avoid rebound effects, and what information they react to or ignore. Here, EL is linked to learning, and so the question of how this literacy can be transmitted to future generations receives special attention. For this reason, in this study, the DEM factor, which is related to participations and skills, is included in the EL scale, especially considering that the academic support related to the SE provided to the students is one of the most important factors in securing EL.

According to Tbilisi Declaration for EE (UNESCO, 1977)	Science Literacy (MoNE, 2005)	Environmental Literacy (Roth, 1992)	Frameworks for developing scale
Knowledge	Key Science Concepts	Knowledge	Environmental Awareness*
	Nature of Science		
Attitude	Attitude and Values in Science	Sensitivity, Attitudes and Values, Personal Investment and Responsibility	Environmental Responsibility*
	Scientific Values		
Skills	Scientific and Technical Psychomotor Skills	Skills	Development of Environmental Behavior
	Scientific Process Skills		
Participation	Science- Technology-Society –Environment Interactions	Active involvement	

*The concepts used in the PISA have been preferred so as not to cause confusion.

Figure 1: Theoretical framework of environmental education (EE), Science Literacy (SL), Environmental Literacy (EL), all of which underpin the framework for the developed scale.

Exploratory factor analysis

A scale was developed for this research. The developed scale was applied on 15-year-old students who were attending schools in Germany. The total sample of this study consisted of 9833 students who were selected using PISA 2006 Data. In the first part of developing the scale, exploratory factor analysis, conducted with the SPSS Program, was used to examine the construct validity of the scale. In the second part, confirmatory factor analysis, conducted with the AMOS Program, was used to show the relationships between variables. Prior to performing the exploratory factor analysis, in order to determine whether or not to conduct a factor analysis, the KMO (Kaiser-Meyer- Olkin) Value and Bartlett’s Test of Sphericity were calculated. The KMO and Bartlett measurement results are presented in Table 1.

Table 1: Kaiser-Meyer-Olkin and Bartlett's Test of Sphericity results

Kaiser-Meyer-Olkin Value		.82
Bartlett's Test Value		28905.55
		105
	p	.00

* p<.01

A KMO Value that is over 0.50 (KMO= 0.82, $p<0.01$) indicates that factor analysis sampling was appropriate. The Bartlett's Test of Sphericity result of 28905.55 ($p<.01$) was significant in that it showed that the measuring tool could be differentiated into factor structures.

Using item-total correlation for the EL scale analysis, the reliability of test items, the t-test for the reliability of the meaningfulness of the median of the top 27% and bottom 27% groups, and the reliability of Cronbach alpha were determined. The results are shown below in Table 2.

Table 2: Item-Total Correlation

Item	t (Bottom 27%-top 27%)[1]
1	33.64***
2	36.89***
3	39.80***
4	38.34***
5	40.69***
6	34.95***
7	10.76***
8	7.48***
9	7.96***
10	11.11***
11	48.21***
12	47.58***
13	50.88***
14	49.56***
15	45.66***

[1] $n_1 = n_2 = 2655$, alpha= .78, N of Items =20, *** $p < .01$

According to the initial data obtained by the exploratory factor analysis, 15 of the items (variables) included in the analysis were gathered under 3 factors and had a value greater than 1. The explanatory variance of these three factors was 47.45%. The commonalities of the 3 factors defined as related to the items should vary between 0.40 and 0.59.

According to the eigenvalue measure, the number of significant factors in the scale was determined to be 3, as clearly seen in Figure 2. While there are 3 factors in the graph with a high ascending curve, the general trend of the graph in the fourth and subsequent factors are horizontal and do not have a significant declining trend. In short, the contributions of the fourth and subsequent factors to the variance are very similar.

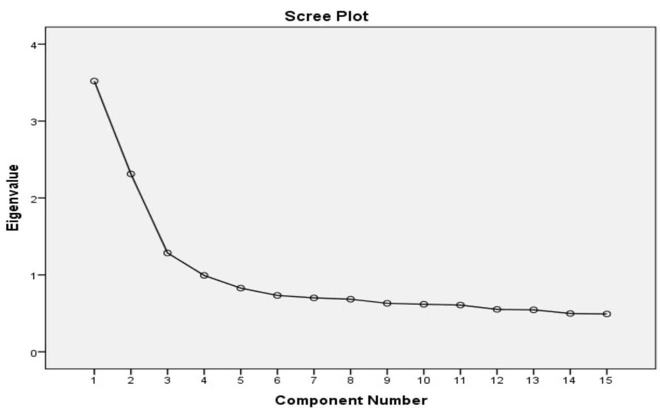

Figure 2: Eigenvalue Graph

Analysis of the scale were made on 3 factors and over 15 items (appendix 1). The analysis of converted basic item components is presented in Table 3.

Table 3: Factor Analysis (analysis of converted basic components)

Item	Factor Common Variance	Factor-1 Load Value	Analysis of converted basic components		
			Factor-1	Factor-2	Factor-3
3	.52	.65	**.70**	.06	.13
4	.47	.65	**.67**	.03	.13
1	.46	.62	**.66**	.04	.12
2	.45	.61	**.65**	.02	.13
6	.47	.61	**.65**	.00	.22
5	.40	.58	**.61**	.11	.11
15	.40	.52	.05	**.75**	.04
12	.51	.51	.05	**.71**	.06
11	.49	.11	.06	**.67**	.06
13	.44	.17	.10	**.65**	.07
14	.56	.22	.04	**.63**	.02
9	.59	.16	.12	.09	**.75**
10	.56	.26	.12	.00	**.74**
8	.43	.53	.21	.01	**.62**
7	.45	.50	.25	.09	**.61**

Explained Variance Total 47.45 %, **Factor-1:** 23.47%, **Factor-2:** 15.42%, **Factor-3:** 8.57 %

Through factor analysis, an attempt was made to bring together variables that measure the same structure with a small number of factors (Buyukozturk, 2009). Item loads larger than 0.61 were chosen and included in the scale. The remaining 15 items were loaded on the 3 factors labelled Environmental Responsibility (ER), Development of Environmental Behavior (DEB), and Environmental Awareness (EA). These factors, along with the number of items attached to them are as follows (see appendix 1):

- Factor-1: Environmental Responsibility (between 1 and 6 items)
- Factor-2: Development of Environmental Behaviour (between 11 and 15 items)
- Factor-3: Environmental Knowledge (between 7 and 10 items)

In summary, although different researchers have preferred to form different EL categories, in this research, three categories (EA, ER, DEB) were established.

Table 4: Correlation of Factors

		EL	ER	DEB	EA
EL	r	1			
	p				
	N	9833			
ER	r	.43**	1		
	p	.00			
	N	9833	9833		
DEB	r	.37**	-.44**	1	
	p	.00	.00		
	N	9833	9833	9833	
EA	r	.73**	.114**	-.02	1
	p	.00	.00	.07	
	N	9833	9833	9833	9833

** p< 0.01

As can be seen in Table 1, there is a positive relationship between EL and the sub factors ($p < .01$).

Confirmatory factor analysis

Structural validity was tested by confirmatory factor analysis, as described above. According to the initial results obtained by confirmatory factor analysis, some of the values were not within the acceptable limits. For this reason, covariance was created between the error terms of the items within each latent variable in the model. The findings are listed in Table 5. Each correction should be made on a theoretical basis (Meydan and Sesen, 2015; Karagoz, 2016). The error terms of the items in each factor were therefore identified (Karagoz, 2016) before performing the confirmatory factor analysis for a second time. The corrected confirmatory factor analysis appeared to be a good fit in general. The notions of good fit and acceptable fit are taken at different value ranges. It is possible that a model may fit the data despite having one or more fit measures that are of a bad fit (Schermelleh-Engel & Moosbrugger, 2003).

Table 5: Fit Criteria (Schermelleh-Engel, Moosbrugger & Müler, 2003) and Model Fit Measures

	Good Fit	Acceptable Fit	Model Fit
c2/sd	$0 \le c^2/sd \le 2$	$2 \le c^2/sd \le 3$	29.49
P	$0.05 \le p \le 1$	$0.01 \le p \le 0.05$	.00
RMSEA	$0 \le RMSEA \le 0.05$	$0.05 \le RMSEA \le 0.08$	.05
NFI	$0.95 \le NFI \le 1.00$	$0.90 \le NFI \le 0.95$	.91
TLI	$0.95 \le TLI \le 1.00$	$0.90 \le TLII \le 0.95$	.88
CFI	$0.97 \le CFI \le 1.00$	$0.95 \le CFI \le 0.97$	.91
RFI	$0.90 < RFI < 1.00$	$0.85 < RFI < 0.90$	.87

As shown in Table 5, the significance value was .00. Moreover, the P-values as well as most of the other values indicate that the model had a good fit.

Findings

Factors influencing Environmental Literacy

In this research, parametric tests (t test) were applied in evaluating the data derived from the analysis of quantitative data. ANOVA, T-test and descriptive statistics were used. The change in ER is included in Figure 3. In Figure 3 and appendix 2, it can be seen that among the factors related to the 'environmental responsibility' –acid rain, food items and garbage –

of the German students, the factor of “acid rain”, with a coefficient of 1.00, had the highest factor value in 2006. However, in 2015 the highest factor was “food items” with a coefficient of 1.04. The factor, “health issue”, had the lowest factor value in 2006, with a coefficient of .76 and in 2015, with a coefficient of .91.

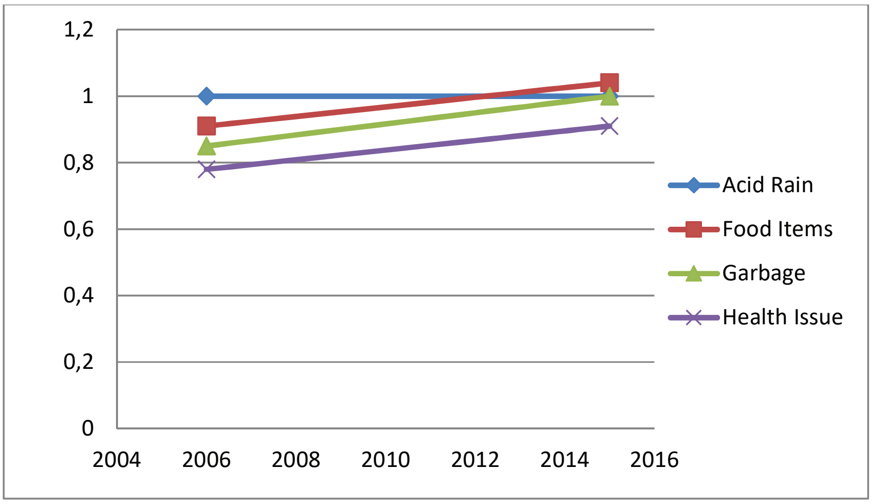

Figure 3: Change in ER based on PISA 2006 data and PISA 2015 data

In Figure 4 and in appendix 2, it can be seen that among the factors related to "development of environmental behaviour" (DEB) in the German students, the factors of “explain ideas” and “practical experiments” had the highest factor value, with a coefficient of 1.33, while the factor of “class debate” had the lowest factor value, with a coefficient of 1.00 in 2006. However, in 2015 the highest factor was “class debate”, with a coefficient of 1.00.

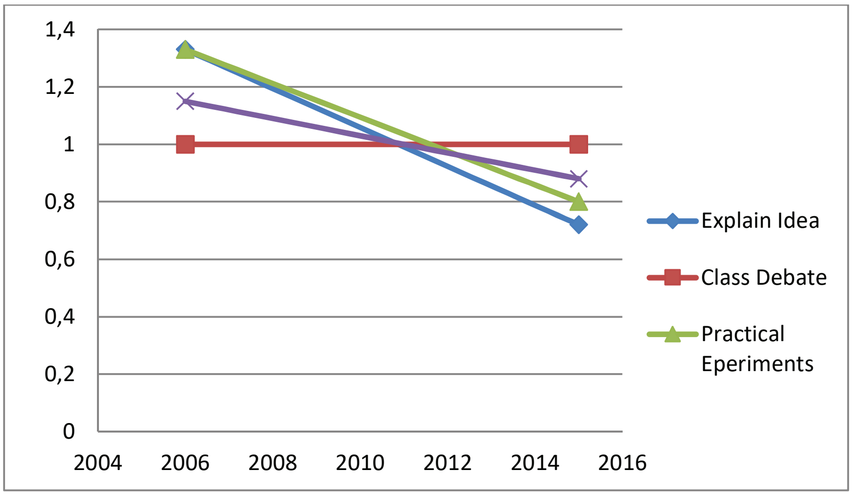

Figure 4: Change in EDB based on PISA 2006 and PISA 2015 data

In Figure 5 and in appendix 2, it can be seen that among the factors related to the "environmental awareness" of the German students, the factor of “greenhouse gases” had the highest factor value in 2006, with a coefficient of 1.12, and in 2015, with a coefficient of 1.07. In addition, the "use of genetically modified organisms (GMO)" had the lowest factor value in both 2006 (with a coefficient of .82) and 2015 (with a coefficient of .72).

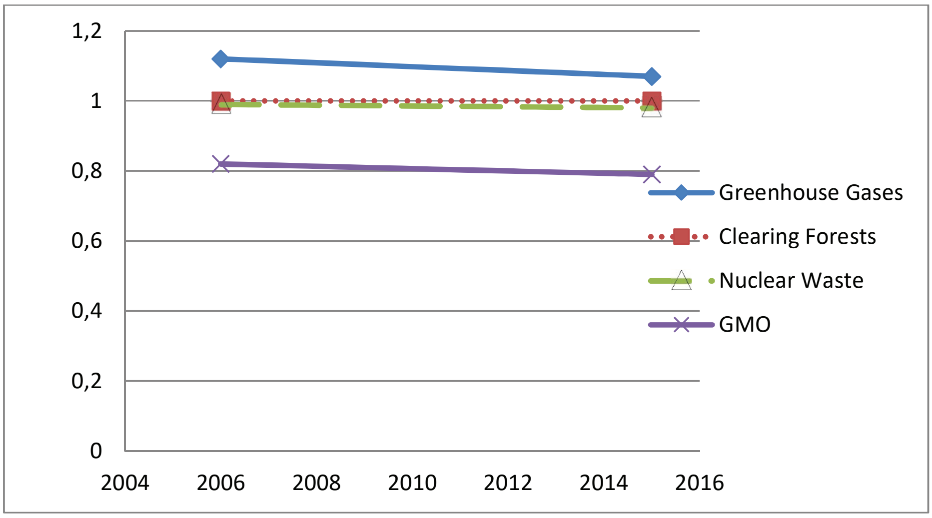

Figure 5: Change in EA based on PISA 2006 and PISA 2015 data

In the questionnaires, the students' views regarding environmental responsibility (ER) were obtained. The responses are shown in Table 6.

Table 6: Views on Environmental Responsibility (questionnaire results)

Year	Environmental Responsibility	I couldn't do this f (%)	I would struggle to do this on my own f (%)	I could do this with a bit of effort f (%)	I could do this easily f (%)
2006	Health Issue	929 (**20.4**)	2640 (**57.9**)	796 (17.5)	193 (4.2)
2015		700 (**20.8**)	1712 (**51.0**)	631 (18.8)	316 (9.4)
2006	Antibiotics	375 (8.2)	1246 (27.3)	1894 (**41.6**)	1041 (**22.8**)
2015		285 (8.6)	818 (24.5)	1424 (**42.7**)	806 (**24.2**)
2006	Garbage	336 (7.4)	1391 (30.6)	2204 (48.4)	619 (13.6)
2015		374 (11.3)	998 (30.2)	1517 (45.9)	419 (12.7)
2006	Certain Species	378 (8.3)	1034 (22.7)	1978 (**43.4**)	1165 (**25.6**)
2015		273 (8.2)	745 (22.5)	1505 (**45.5**)	788 (**23.8**)
2006	Food Items	421 (9.2)	1335 (29.3)	1897 (41.7)	901 (19.8)
2015		398 (12.1)	983 (29.9)	1349 (41.1)	555 (16.9)
2006	Acid Rain	536 (**11.8**)	1105 (24.2)	1719 (37.7)	1199 (26.3)
2015		556 (**17.0**)	894 (27.3)	1201 (36.6)	626 (19.1)

As shown in Table 6, the majority of the students (63% and over) indicated that 'they can describe the role of antibiotics in the treatment of disease' and 'they can predict how changes to an environment will affect the survival of certain species' easily on their own in both 2006 and 2015. However, approximately 20 % of the German students pointed out that they could not recognize on their own the science question underlining a newspaper report on a health issue. Moreover, more than half of the students mentioned that they struggled to understand the health issue. An increase was seen in the percentage of students who stated they could not identify the better of two explanations for the formation of acid rain, from 2006 (11.8%) to 2015 (17%).

In the questionnaires, the students' views regarding academic development support were obtained. The responses are shown in Table 7.

Table 7: Views on Development of Environmental Behaviour (questionnaire results)

Year	**Development of Environmental Behaviour**	Never or hardly ever f (%)	In some lessons f (%)	In most lessons f (%)	In all lessons f (%)
2006	Explain Ideas	1004 (**22.2**)	1683 (37.2)	1394 (30.8)	441 (9.8)
2015		1394 (**30.3**)	1843 (40.0)	1024 (22.2)	345 (7.5)
2006	Practical Experiments	1135 (25.1)	2406 (53.3)	819 (18.1)	157 (3.5)
2015		1254 (27.4)	2333 (50.9)	808 (17.6)	186 (4.1)
2006	Draw Conclusion	378 (8.4)	1212 (27.0)	1933 (43.1)	958 (21.4)
2015		484 (11.0)	1315 (29.8)	1775 (40.2)	842 (19.1)
2006	Design Own Experiments	2776 (**62.0**)	1106 (24.7)	454 (10.1)	145 (3.2)
2015		2837 (**64.0**)	1026 (23.1)	402 (9.1)	168 (3.8)
2006	Class Debate	705 (**15.6**)	2038 (45.1)	1254 (27.7)	526 (11.6)
2015		972 (**22.0**)	1753 (39.6)	1286 (29.1)	414 (9.4)

As shown in Table 7, in 2006, 62% of the students reported that in science lessons they were never or hardly ever allowed to design their own experiments, and 25 % mentioned that they never or hardly ever spent time in the laboratory doing practical experiments as part of the science lessons. Furthermore, 22 % indicated that they never or hardly ever were given opportunities in the science lessons to explain their ideas. However, in 2015, 64% of the students reported that they never or hardly ever were allowed to design their own experiments in science lesson, 30% reported that they never or hardly ever were given opportunities in the science lessons to explain their ideas, and finally, 27% mentioned that never or hardly ever spent time in the laboratory doing practical experiments as part of the science lessons.

In the questionnaires, the students' views regarding environmental awareness were obtained. The responses are shown in Table 8.

Table 8: Views on Environmental Awareness (questionnaire results)

Year	Environmental Issue	I have never heard f (%)	I have heard about this but I would not be able to explain what it is really about f (%)	I know something about this and could explain the general issue f (%)	I am familiar with this and I would be able to explain this well f (%)
2006	The increase of greenhouse gases	465 (10.2)	1376 (30.1)	1823 (39.9)	901 (19.7)
2015		464 (11.1)	949 (22.8)	1686 (40.5)	1066 (25.6)
2006	The use of GMO	817 (**17.9**)	2005 (44.0)	1410 (30.9)	329 (7.2)
2015		968 (**23.4**)	1683 (40.7)	1114 (27.0)	366 (8.9)
2006	Nuclear waste	311 (6.8)	1457 (32.0)	1958 (43.0)	832 (18.3)
2015		317 (7.7)	1111 (27.0)	1804 (43.8)	888 (21.6)
2006	The consequences of clearing forests	248 (5.4)	676 (14.8)	1716 (**37.6**)	1925 (**42.2**)
2015		230 (5.6)	620 (15.1)	1753 (**42.7**)	1501 (**36.6**)

As shown in Table 8, in 2006 and 2015, the majority of the German students (80%) pointed out that they had information about the consequences of clearing forests for other land use. More than 60% of the German students indicated in 2006 and 2015 that they had knowledge about nuclear waste. On the other hand, in 2006 and 2015, more than 60% of the German students believed that they did not have sufficient knowledge about the use of GMO. Table 9 presents the mean of the German students' EL (environmental literacy) and sub-factors.

Table 9: Mean of German students' EL and sub-factors

	2006		2015	
	Mean	**Participant**	**Mean**	**Participant**
EL	2.55	4891	2.58	4942
ER	2.20	4891	2.28	4942
EDB	2.72	4891	2.73	4942
EA	2.72	4891	2.73	4942

As shown in Table 9, the means of EL were 2.55 in 2006 and 2.58 in 2015. Therefore, there was an increase in the mean of the EL from 2006 to 2015.

Environmental Literacy and Interest in Science

The results of ANOVA, as related to EL and having fun when learning science, were obtained. The responses are shown in Table 10.

Table 10: The results of ANOVA, as related to EL and having fun when learning science

	View	N	$\bar{X}$	Source of Variance	Sd	Mean Square	F	p	Sig dif
2006	Strongly agree(a)	1145	1.87	Between groups	3	1.90	24.82	.00	a-b, a-c, a-d
	Agree(b)	1850	2.15	With-in group	4702	.08			
	Disagree(c)	1273	2.41	Total	4705				
	Strongly disagree(d)	438	2.73						
2015	Strongly agree(a)	899	2.57	Between groups	3	.176	1.93	.12	-
	Agree(b)	1499	2.58	With-in group	4058	.091			
	Disagree(c)	1044	2.60	Total	4061				
	Strongly disagree(d)	620	2.57						

The results of the analysis show that there was a meaningful difference in terms of EL averages and having fun when learning science topics in 2006 (F_{2006} (3, 4702) =24.82, p < .01), whereas in 2015 there was no meaningful difference (F_{2015} (3, 4058) =1.93, p > .01). According to the results of the Scheffe test, the EL of the students who strongly disagreed with the fun of learning science (d) (X =2.73) was stronger than that of the other students in 2006. Moreover, while there was a significant increase from 2006 to 2015 in the average of the students who strongly agreed with the fun of learning science (X= 1.87) (X =2.57), there was a decrease in the average of the students who strongly disagreed with the fun of learning science (X_{2006} = 2.73; X_{2015} = 2.57).

Table 11 shows the results of ANOVA as related to EL and the interest in learning about science.

Table 11: The results of ANOVA as related to EL and the interest in learning about science

	View	N	X̄	Source of Variance	sd	Mean Square	F	P	Sig Dif
2006	Strongly agree(a)	1015	2.51	Between groups	3	2.45	32.03	.00	a-c, a-d
	Agree(b)	1799	2.53	With-in group	4699	.08			
	Disagree(c)	1331	2.57	Total	4702				
	Strongly disagree(d)	558	2.64						
2015	Strongly agree(a)	794	2.56	Between groups	3	.379	4.13	.006	-
	Agree(b)	1492	2.57	With-in group	4023	.092			
	Disagree(c)	1032	2.60	Total	4026				
	Strongly disagree(d)	709	2.60						

The results of the analysis show that there was a meaningful difference in terms of EL averages and interest in learning about science between 2006 and 2015 (F_{2006} (3.4699) =32.03, F_{2015} (3.4023) =4.13, $p < .01$). According to the results of the Scheffe test, the EL of the students who strongly disagreed with interest in learning about science was stronger than that of the other students in 2006 ($X_{2006} = 2.64$) and 2015 ($X_{2015} = 2.60$). However, by 2015, the averages of those who strongly disagreed with the interest in learning science decreased, while the averages of those who strongly agreed with the interest increased.

Environmental Literacy and Reading Science

The results of ANOVA, as related to EL and like reading science, were obtained. The responses are shown in Table 12.

Table 12: The results of ANOVA, as related to EL and like reading science

	View	**N**	**$\bar{X}$**	**Source of Variance**	**sd**	**Mean Square**	**F**	**p**	**Sig Dif**
2006	Strongly agree(a)	1421	2.51	Between groups	3	2.34	30.52	.00	a-b, a-c, a-d
	Agree(b)	585	2.52	With-in group	4704	.08			
	Disagree(c)	1921	2.55	Total	4707				
	Strongly disagree(d)	781	2.62						
2015	Strongly agree(a)	518	2.55	Between groups	3	.787	8.67	.00	
	Agree(b)	1128	2.57	With-in group	4031	.09			d-a, d-b, d-c
	Disagree(c)	1453	2.58	Total	4034				
	Strongly disagree(d)	936	2.62						

The results of the analysis show that there was a meaningful difference in terms of EL averages and like reading science between 2006 and 2015 (F_{2006} (3.4704) =30.52, F_{2015} (3.4031) =8.67, $p < .01$). According to the results of the Scheffe test, the EL of the students who strongly disagreed with like reading science was stronger than the EL of the other students in 2006 (X_{2006} = 2.62) and 2015 (X_{2015} = 2.62). However, by 2015, the averages of those who strongly disagreed with like reading science stayed at the same value, while the averages of those who strongly agreed with like reading science increased.

Environmental Literacy and Teaching Methods

The results of ANOVA, as related to EL and teacher's explanation about how a school science idea can be applied were obtained. The responses are shown in Table 13.

Table 13: The results of ANOVA, as related to EL and teacher's explanation about how idea can be applied

	View	N	$\bar{X}$	Source of variance	Sd	Mean Square	F	P	Sig Dif
2006	All lessons (a)	792	2.44	Between groups	3	8.67	116.25	.00	a-b, a-c, a-d
	Most Lessons(b)	1797	2.52	With-in group	4483	.08			
	Some lessons (c)	1463	2.60	Total	4486				
	Hardly ever (d)	435	2.71						
2015	All lessons (a)	749	2.43	Between groups	3	12.73	160.71	.00	a-b, a-c, a-d
	Most Lessons(b)	1720	2.54	With-in group	4387	.08			
	Some lessons (c)	1471	2.65	Total	4390				
	Hardly ever (d)	451	2.74						

The results of the analysis show that there was a meaningful difference in terms of EL averages and teacher's explanation about how idea can be applied between 2006 and 2015 (F_{2006} (3.4483) = 116.25, F_{2015} (3.4387) =160.71, $p < .01$). According to the results of the Scheffe test, when students were never or hardly ever informed by the teachers in the science lessons (d) (X_{2006} = 2.71; X_{2015}=2.74), the EL average of the students was stronger than that of the other students. From 2006 to 2015, the literacy average increased when the teacher never or hardly ever offered explanations during their science lessons.

The results of ANOVA, as related to EL and teacher's provision of an explanation of the relation of science concepts to our life, were obtained. The responses are shown in Table 13.

Table 13: The results of ANOVA, as related to EL and teacher's provision of an explanation of relation of science concepts to our life

	View	N	$\bar{X}$	Source of Variance	Sd	Mean Square	F	P	Sig Dif
2006	All lessons (a)	417	2.40	Between groups	3	8.81	118.49	.00	a-b, a-c, a-d
	Most Lessons(b)	1296	2.49	With-in group	4456	.074			
	Some lessons (c)	1972	2.57	Total	4459				
	Hardly ever (d)	775	2.67						
2015	All lessons (a)	457	2.39	Between groups	3	12.10	153.16	.00	a-b, a-c, a-d
	Most Lessons(b)	1175	2.52	With-in group	4380	.08			
	Some lessons (c)	1745	2.61	Total	4383				
	Hardly ever (d)	1007	2.69						

The results of the analysis show that there was a meaningful difference in terms of EL averages and teacher explaining the relation of science concepts to our life between 2006 and 2015, F_{2006} (3.4456) =118.49, F_{2015} (3.4380) =153.16, $p < .01$. According to the results of the Scheffe test, when students are never or hardly ever informed about the relevance of science concepts to our lives by teachers in the science lessons (d) (X_{2006} = 2.67; X_{2015}=2.69), the EL average of the students was stronger than that of the other students. The El average was found to increase when the teacher never or hardly ever provided explanations about the relevance of science concepts to our lives during their science lessons.

Discussion

According to 2006 and 2015 data, the students constituting the study had more knowledge about greenhouse gases than about other items. More than half of the German students had knowledge on the greenhouse gases, the consequences of clearing forests for other land use, and nuclear waste, in 2006 and 2015. In line with this finding, in the research conducted by Yurttas and Sulun (2010), second-grade primary school students specified global warming, ozone layer depletion and acid rain to be the biggest environmental problems in the world. In another study which reported similar results, elementary students were shown to be mostly aware of the environmental problems stemming from environmental contamination, air pollution and waste materials (Demirbas and Pektas, 2011). To continue, in a study by Negev et al. (2010), it was reported that most of the twelfth-grade student participants indicated solid waste, or air pollution, to be major environmental issues. In general, studies have shown that students view air pollution, global warning and greenhouse gases as the most important environmental issues. People tend to have more knowledge about matters that have a concrete impact on their lives. Moreover, social media has helped to draw attention to global problems, including of course those related to environmental issues. The study by Incekara and Tuna (1991) give support to the role that social media plays in spreading environmental knowledge, as they reported that secondary students tended to have sufficient information on issues such as air pollution, desertification and climate change. Similar results have been observed in research conducted on the environmental awareness of teacher candidates. In a study conducted by Artun, Uzunoz and Akbas (2009), teacher candidates pointed to global warming and air pollution as important environmental problems. Diken and Sert Cibik (2007) suggested that teacher candidates have cognitive and sensitive dimensions of environmental consciousness. However, these dimensions are not sufficient in terms of reflecting the environmental knowledge they have onto their behaviours (Diken and Sert Cibik, 2007; Kaya et al., 2009). This could be attributed to their lack of environmental awareness (Guven and Aydogdu, 2012; Ercengiz, et al., 2014). According to the study by Kahyaoglu et al. (2008) environmental behaviour is influenced environmental knowledge and awareness. Therefore, teacher candidates, especially science teachers, should be provided the necessary support to increase their level of environmental awareness, and they should be encouraged to translate their environmental awareness into environmentally responsible behaviour. For the sake of securing our future, it is crucial that students be taught a high level of environmental awareness. The German students in the present study had the lowest awareness of “use of GMO” in 2006 and 2015. However, interestingly, more students in 2015 seemed to have never heard of this concept. When the opinions of the students were taken to determine their knowledge level on this subject, the German students reported that they did not have sufficient knowledge about GMOs. Similarly, in a separate study, it was found from the opinions taken of students that they had insufficient information and misleading concepts about greenhouse gases (Bahar and Aydin, 2002). These results were in line with those from Darcin et al. (1991), who reported that the levels of knowledge elementary students had on the greenhouse effect were too low. In another study, it was indicated that biology teacher candidates had incorrect ideas about the greenhouse effect (Selvi and Yildiz, 2009). Regarding the subject of GMO, Gurbuzoglu Yalmanci (2016) reported that both high school students and teacher candidates had some misunderstandings about GMO. University students too have been shown to not have enough knowledge about GMO (Temelli and Kurt, 2011). In a study conducted by Cankaya and Filik Iscen (2015), however, it was stated that science teacher candidates had sufficient information about the meaning of the concept of GMO, although, they did have incorrect knowledge about the production of GM crops, the use of GMO in their country, and their effects.

Despite the increase in the health coefficient from 2006 to 2015, it was nonetheless seen that health issues are still not given importance (appendix 2). In support of this finding, approximately 20% of the German students, in both 2006 and 2015, revealed that they were unable to recognize a health problem. Moreover, more than half of the students mentioned that they struggled to understand the health issue. Research shows that overuse of antibiotics poses a threat, not only to human health but also to the environment (Yesil Aski, 2013).

Individuals need to be taught greater awareness about health issues in order to create a healthier public in the future. In addition to the lack of understanding of health issues, it was also found that there was an increase in the percentage of the students who indicated that they were unable to explain acid rain. Therefore, acid rain and health issues should be emphasized in future science curricula.

While in 2006 the students stated that they were not able to express themselves enough in science classes, in 2015, the students mentioned class discussions and their expectations regarding the planning of science lessons so as to allow for the discussion of different opinions. On the other hand, in both 2006 and 2015, approximately 25% of the students reported that they never or hardly ever spent time in the laboratory doing practical experiments as part of their science lessons. Furthermore, more than half of the students noted that they never or hardly ever were allowed to design their own experiments in the science lessons. It can be seen from the students expressed expectations that they would like their science lessons to be more student-centred. In other words, they want to actively participate in the process by taking responsibility in lessons. When the teacher never or hardly ever provides explanations showing the relevance of science concepts to our lives or/and explanations about how a school science idea can be applied during a science lesson, the average rate of EL increases. In fact, it can be argued that teacher-centred education has a negative effect on EL. Therefore, student-centred lessons should be applied to provide more academic support for the improvement of EL skills. A student-centred approach also provides opportunities for students to increase their interest and attitude towards science. If these are increased, the students will have a chance to improve their literacy. Interest and positive attitude towards science, academic development support and EL are concepts that affect each other.

Last but not least, in this study, there was a positive relationship determined between EL and ER and ADS and EA (Figure 6). Otherwise stated, when EA, ER and DEB are positively supported, this will provide a positive contribution to the students' EL development.

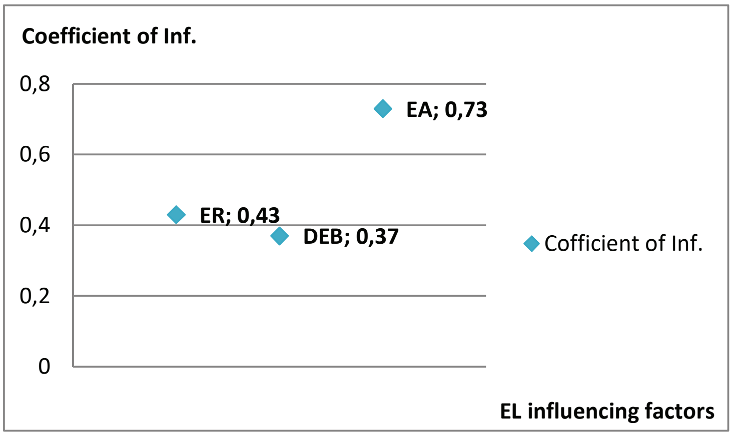

Figure 6: Environmental Literacy (EL) influencing the factors of Environmental Awareness (EA), Environmental Responsibility (ER), and Development of Environmental Behaviour (DEB).

Implications

First, when PISA 2006 and 2015 data were compared, it was initially anticipated that the increase in the average of EL would positively impact EE and thereby, in turn, contribute positively to EL between these years.

What are the challenges and solutions for school education?

According to the results gathered in the study, it might be said that the subjects of genetically modified organisms and health issues should be more comprehensively taught as part of the science curricula in Germany. Teachers should allow students to access new information instead of simply sharing information with students. The students' interest and attitudes towards science should be improved, and students should be encouraged to read science books.

Students should be informed about the effect of these on the environment, and in social terms, individuals should have raised awareness of these issues. Furthermore, teachers especially science and biology teachers, should be informed about these issues through in-service training.

In addition, science teachers should design classroom environments in which

- students can express their thoughts,
- students can engage in class discussions, and
- students have access to new knowledge during EE.

Ultimately, it is important that teachers are aware of the changing roles of EE, that they design student-centred education and/or that they facilitate inquiry-based learning in the classroom environment. Moreover, it is important that improvements be made to secure the professional development and science process skills of the students. Lastly, the importance, scope and competencies of EL should be determined more clearly to ensure a higher quality of SE.

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Appendix 1: Items on the Scale

Factor Name	Code	Items
Development of Environmental Behavior	ST098Q01TA	Students are given opportunities to explain their ideas.
	ST098Q02TA	Students spend time in the laboratory doing practical experiments.
	ST098Q05TA	Students are asked to draw conclusions from an experiment they have conducted.
	ST098Q07TA	Students are allowed to design their own experiments.
	ST098Q08NA	There is a class debate about investigations.
Enviromental Awareness	ST092Q01TA	How informed are you about this environmental issue? The increase of greenhouse gases in the atmosphere
	ST092Q02TA	How informed are you about this environmental issue? The use of genetically modified organisms (<GMO>)
	ST092Q04TA	How informed are you about this environmental issue? Nuclear waste
	ST092Q05TA	How informed are you about this environmental issue? The consequences of clearing forests\other land use
Enviromental Responsibility	ST129Q01TA	Recognise the science question that underlies a newspaper report on a health issue.
	ST129Q03TA	Describe the role of antibiotics in the treatment of disease.
	ST129Q04TA	Identify the science question associated with the disposal of garbage.
	ST129Q05TA	Predict how changes to an environment will affect the survival of certain species.
	ST129Q06TA	Interpret the scientific information provided on the labelling of food items.
	ST129Q08TA	Identify the better of two explanations for the formation of acid rain.

Appendix 2: Structural Equation Modeling of Environmental Literacy (Appendix 1)

Sub-Factor	PISA	The First Important Item	Coeff.	The Second Important Item	Coeff.	The Third Important Item	Coeff.	The Last Item	Coeff.
ER	2006	Acid Rain	1,00	Food Items	,91	Certain Species	,88	Health Issue	,78
	2015	Food Items	1,04	Garbage	1,00	Acid Rain	1,00	Health Issue	,91
DEB	2006	Explain Ideas	1,33	Practical Experiments	1,33	Design Own Experiments	1,19	Class Debate	1,00
	2015	Class Debate	1,00	Draw Conclusion	,88	Practical Experiments	,80	Explain Ideas	,72
EA	2006	Greenhouse Gases	1,12	Clearing Forests	1,00	Nuclear Waste	,99	GMO	,82
	2015	Greenhouse Gases	1,07	Clearing Forests	1,00	Nuclear Waste	,98	GMO	,79

2.1.1.3. Comparison of the Main Determinants Affecting Environmental Literacy in Singapore, Estonia and Germany

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Abstract

The purpose of this research is to determine and compare the variance of the main factors affecting the environmental literacy of fifteen-years-old students studying in Singapore, Estonia and Germany. The relational model, which is one of the quantitative research approaches, has been adopted in this study. Through the relational model, the main factors affecting the environmental literacy averages of the sample countries and the degree of the effect of these factors have been investigated. As the research design, a survey method that provides the opportunity to work with a large sample was used. In this study, the universe was 15-years-old German, Singaporean and Estonian students. The sample consisted of 6.504 German, 6.115 Singaporean and 5.587 Estonian students. The data based on the findings of the PISA 2015. In this study, the researchers used Environmental Literacy Scale developed by researchers. It was also classified by the researchers to determine the basic determinants affecting environmental literacy. In the light of the selected determinants, it is concluded that in all three countries there is a low but significant relationship between environmental literacy and the determinants affecting the environmental literacy. In Estonian case, there are various factors affecting environmental literacy furthermore, the total

variance ratio is lower than the other two countries. In German case, the determinants (extra-curricular activities, teacher's teaching skills etc.) affecting environmental literacy were few and the variance rate was about the same as that of Singaporean. "Extra-curricular activities" is the determinant which had the most significant positive impact on environmental literacy among students in all three countries.
Keywords: environmental literacy; science education; country-comparative study

Introduction

Literacy, especially the environmental literacy, is one of the important concepts for the improvement of sustainable development awareness of future generations. Thus, studies in the field of environmental literacy, analysing the positive practices of different countries in environmental education may contribute to the future generations' awareness towards nature. Therefore, this study includes both the comparison of environmental literacy and the concept of environmental literacy of the countries selected by the researchers. For a better understanding of the subject, firstly, the environmental literacy and factors affecting literacy will be explained. Then information concerning the importance and purpose of this study will be given in the following paragraphs.

Environmental Literacy

Since the 1970s, the concept of environmental literacy arisen as a concept that has to be taken into consideration in the solution of the environmental problems (Ozturk, Tuzun and Teksoz, 2013). Nevertheless, after nearly twenty years (in the 1990s), the concept of environmental literacy witnessed the improvement of EE (McBeth and Volk, 2010). In fact, although there is no universal definition (Loubser, Swanepoel and Chacko, 2001; Morrone, Mancl and Carr, 2001), researchers have divided environmental literacy into various categories. In one of these studies, environmental literacy has four major components: knowledge skills, affect and behaviour (Roth, 1992). In another study, it is mentioned that environmental literacy (EL) has five categories of concepts including; awareness, knowledge, attitude, skills, and participation (Wisconsin Department of Public Administration, 1991). According to PISA analyses, the categories of environmental literacy involve awareness, responsibility and optimism towards the environment (Kaya and Elster, 2017a) as well as the development of environmental behaviour (Kaya and Elster, 2017b).

In order to have a more sustainable prospect in the future by the societies, some of the studies related to environment in SE are carried out to define and classify the environmental literacy. Environmental literacy is regarded as a conscious management and use of natural resources at individual level (Bennett and Roth, 2015), studies on environmental literacy will continue to achieve this aim at the desired level.

Purpose of Study

A good formal education should be assessed through including the performances of the students (Modupe, 2012). This might be an effective feedback of the success of the educational system. A similar situation is generally viable for both SE and especially for the EE. It is assumed that the determination of factors raising more qualified environmental literate individuals should be taken into consideration. In addition, the proposal of solutions in this direction will lead to the increase of the quality of formal education as well as the protection of existing natural resources. Moreover, in order to improve the quality of EE, it is expected that more comprehensive solution proposals will be put forward to train qualified environmental literate individuals as they are obtained from the data of the international study PISA. The purpose of this study is to determine the factors affecting environmental literacy in Germany, Estonia and Singapore. A further aim is to compare the factors which are affecting the environmental literacy in these countries. These countries are chosen because when the PISA 2015 data are analysed the highest average among participants in SL was in Singapore and Estonia had highest average among the participants of the European countries (OECD, 2016).

Review of Literature

The factors affecting literacy are given under four main headings including; the effects of the family, teacher, student and teaching.

The Effects of the Family

Empirical studies have proven that “Family” is the main factors influencing the quality of education, student achievement and literacy. Apart from the education given in the school, it seems that parents have an active role on the success of the students (Aslanargun, 2007; Cagdas, Ozel and Konca, 2016). When Hattie's study is analysed, one of the obvious family-related factors is socio-economic characteristics and the other is the participation of the family (Lotz and Lipowsky, 2015). Families involved in the child's education process, are supporting to make positive development both in themselves and in their children and also in educational institutions (Cagdas, Ozel and Konca, 2016). However, the educational achievement of the family is regarded as an important factor in order the child to be effectively involved in the educational process (Usher and Kober, 2012; Henderson, 1987). Furthermore, economic, social and cultural structures not only affect education but also environmental literacy (Lin and Shi, 2014). It is stated that there is a meaningful and positive relationship between socio-economic level of the family and environmental literacy (Kaya and Elster, 2017a). To sum up, family-related factors should be taken into consideration in order students to be more successful and more qualified environment literate individuals.

The Effects of the Teacher

In the life of students, there are two basic educators: their parents and their teachers (Department for Children, Schools and Families, 2008). For this reason, the effectiveness of the teacher has often been a matter of debate in former and current times (Kaya, Godek Altuk, and Bahceci, 2012; Kisakurek, 2009; Tatar, 2004). The focal point of these discussions is to get the better education for the students (Kaya, Godek Altuk, and Bahceci, 2012).

Increasingly broadening teacher competencies are influential on student achievement, particularly the teacher's tendencies and competencies related to teaching, classroom management, academic support and attitudes towards his/her student. The teacher should use effective methods and appropriate materials in the teaching process therefore students can acquire the necessary skills and perform effective learning (Simsek, Hirca and Coskun, 2012). For example, student-cantered teaching methods, such as creative drama (Batdi and Batdi, 2015; Akdemir and Karakus, 2016), 5E teaching methods (Acisli, Altun Yalcin and

Turgut, 2011; Crider, 2013), and inquiry-based learning (Simsek and Kabapinar, 2010), are generally more likely to impact academic achievement than traditional teaching methods. Therefore, in order to enable the teacher to use the teaching process effectively, professional development should be supported by starting from the pre-service and including in the process (Kaya and Gödek, 2016).

In addition to teaching methods, the teacher's academic support to students and attitudes towards them and classroom management are also affecting student success. For this reason, an effective teacher ought to know his/her students well and show their love towards them (Sahin, 2011). In addition, the instructor should motivate his/her student by guiding him/her and encourage them to learn within the teaching process. When the teacher has effective in the sense of professional development, effective teacher behaviour might be demonstrated and effective classroom management might be realized (Can, 2004). For this reason, the influence of the teacher on the success of education must be considered.

The Effects of the Student

One of the factors affecting literacy is the student himself. In addition to the students' attitudes towards the school and lessons, and the anxiety of the exam, there are various factors influencing the students' success. Attitudes are regarded as one of the affective characteristics that affect learning (Yasar and Anagun, 2008) so that, students' attitudes towards science affect students' success in science (Unal and Ergin, 2006). However, education systems force students unnecessarily, it causes students to develop negative attitudes towards reading, teaching and learning (Moore, 2004). The cause of negative effects is not only related to the personality of the student, but also the qualities (content knowledge ve pedagogical knowledge) of the teacher (Tomal, 2010). In order to become lifelong learners, students should be supported in terms of their knowledge, understanding and attitudes towards natural sciences (Kaya and Boyuk, 2011).

The Effects of the Teaching

Another important factor affecting literacy is teaching. Diversity in teaching methods and forms, and effective planning of the process, are the factors that affect both the literacy and the success of the student. Therefore, it is necessary to apply teaching methods and techniques in the right place and at the right time by observing the characteristics of the teaching environment (Yasul and Samancı, 2015). For instance, a teacher who teaches teamwork in his/her classroom should allow the students to solve the problems in pair, get mutual feedback, and share information with other members of the group (Hevedanlı and Akbayın, 2006).

For the student success not only formal learning process but also informal process learning are important. Extra-curricular activities in students' development, activities that reinforce students' learning in the formal learning process, demonstrate that these learnings are related to life, and put the theoretical learning into practice (Kose, 2013). For this reason, many educational institutions, especially in the field of science, provide their students with extra-curricular learning experiences, (Eastwell and Rennie, 2002; Bostan Sarioglan and Kucukozer, 2017). In this way, students are able to learn by doing actively, gain an inquisitive point of view and use scientific process skills (Ay, Anagün and Demir, 2015). In conclusion, education and training are not only limited to schools, but also out-of-school processes. For this reason, it is important to consider that effective use of out-of-school activities will have the opportunity to raise qualified literate individuals, especially environmental literate individuals.

Previous Research in Factors Influencing Literacy

Yildirim(2012) used the PISA 2006 data and found that the factors determining education quality in Turkey were family factor (% 52), student characteristics factor (%14), teaching process factor (% 6) and institutional environment factor (%1,4). In another study, it was found that there was a positive and statistically significant impact of learning facilities, communication skills and proper guidance from parents on student academic performance (Singh, Malik and Singh, 2016). In Becker and Luthar's study (2002), it was stated that academic and school attachment, teacher support, peer values, and mental health are influential on achievement performance. In another study, it was found that socio-economic, psychosocial, school and home environment and student's own factors, affected their academic performance (Habibullah and Ashraf, 2013). In addition, attitudes towards science affects the success (Akpınar, Yıldız, Tatar and Ergin, 2009; Ali, Iqbal and Akhtar, 2015; Criker, 2006). In the meta-analysis study Hattie (2009) examined five basic categories of situations that affect learning which are home, student, school, curricula, and teacher. In another meta-analysis study, the school-related factors affecting the academic achievement were found by Sarier (2016), as 0.23 for the effect size of the students; student-related factors were found as 0.32; and family related factors were found as 0.27. Furthermore, the most important factors affecting the academic success of the students were found to be socio-economic status, self-efficacy and motivation.

In addition, the literature also includes studies on factors affecting both academic and science achievement. In Anıl's study (2009), it was determined that the variables that most predict students' success in science in PISA 2006 data were 'the educational status of the father', 'the attitude towards science', and 'the computer environment'. In his study, Anıl (2011) determined that the most important variable that determines the success of the students' science achievement and the most important factor determining success were 'time', 'environment', 'education' and 'attitude'. In a study conducted with 10th grade students (300 male and female), Farooq et al., (2011) found that socio-economic status (SES) and parents' education had a significant effect on students' overall academic achievement. In Sayin and Gelbal's study (2014), the most important factors in the success of the teacher candidates were found to be the good listening skills, disciplined work, the strategies and methods applied with teacher competencies; the less important factors were found to be the number of siblings, computer skills and participation in social activities.

Similar results have been obtained in studies conducted in different interdisciplinary fields. In one of these studies, it has been seen that there was a relationship between the income level of the family, the attitude towards the course and mathematics success. In Demir, Kılıç and Depren's study (2009), the student background, learning strategies, self-related cognitions in mathematics and school climate factors under study totally accounted for approximately 34 percent of the variance in mathematics achievement. All of the factors had statistically significant effects on the achievement. Lamb and Fullarton (2001) mentioned that according to TIMSS data, classroom differences account for about one-third of the variation in mathematics achievement in the United States and over one-quarter in Australia.

Research Questions

The purpose of this research is to determine the variance of the main factors affecting the environmental literacy of the fifteen-years-old students in Germany, Singapore and Estonia. Within the scope of this aim, answers to the following questions were sought:

- What are the main factors influencing the environmental literacy of the students in the age group of fifteen in Singapore, Estonia and Germany? How is the similarity between countries considering whether they are statistically significant or not?

- How much of the explained variance of the students' perceptions of environmental literacy averages is explained by the main factors covered in this research? How are the rates of disclosure compared to the countries?

Research Methods and Design

In this section, the type of study, sampling, data collection and the data analysis will be explained.

Type of Study

The relational model, which is one of the quantitative research approaches, has been adopted in this study. Through the relational model, it was tried to determine the main determinants affecting the environmental literacy averages of the sample countries and the degree of the effect of these factors. As a research design, a survey method that provides the opportunity to work with a large sample was used. Survey method is a research aimed to identify the views and the situations of large masses (Buyukozturk, Kilic Cakmak, Akgun, Karadeniz and Demirel, 2008).

Sample and Sampling

When the sample is determined, it is also aimed to specify and compare the main factors affecting the environmental literacy of the students in Germany, Singapore and Estonia. The reason for comparing the environmental literacy of German students to Singaporean and Estonian students is that when the PISA 2015 data are analysed the highest average among participants in SL was in Singapore and Estonia had highest average among the participants of the European countries (OECD, 2016). For this reason, these three countries were compared in regard to environmental literacy. In this study, the universe was 15-years-old German, Singaporean and Estonian students. The sample consisted of 6.500 German students, 6.115 Singaporean students and 5.587 Estonian students. PISA 2015 data were obtained on the internet from the official PISA web site (http://www.pisa.oecd.org) are used.

Measures

In this study, environmental literacy scores of the students were considered as dependent variables. Researchers used Environmental Literacy Scale developed by Kaya and Elster (2017b) to calculate students' scores. According to Kaya and Elster (2017b), the remaining 15 items were loaded on the 3 factors labelled environmental responsibility, development of environmental behaviour, and environmental awareness. Item loads larger than 0.61 were chosen and included in the environmental literacy scale. In the first part of developing the scale, exploratory factor analysis, was used to examine the construct validity of the scale as described above In the second part, confirmatory factor analysis, was used to show the relationships between variables. According to results of confirmatory factor analysis, the significance value was found to be .00, as well as, the P-values and most of the other values may be interpreted as indicating good fit.

Moreover, as some independent variables, they are considered as the main determinants affecting literacy. The 71 items selected from the student questionnaires in the PISA data were also classified in 14 categories by the researchers to determine the basic determinants affecting literacy. The following paragraph makes a more detailed knowledge of classification of factors.

Classification of the Main Determinants Affecting Literacy

Even though the validity and reliability of PISA tests and questionnaires are achieved through different approaches (Yildirim, 2012), in the first part of the classification of main determinants, exploratory factor analysis with SPSS software was used to examine the construct validity of the scale. Exploratory factor analysis (EFA) are widely used in education (Taherdoost, Sahibuddin and Jalaliyoon, 2014) and statistically used in this study. EFA is normally the first step in building scales or a new metrics (Yong and Pearce, 2013). Before the items are classified, due to some of the items in this study are categorical variables, they are included in the analysis by converting them into new artificial variables called "dummy" variables. Since, the observation of the effects of the qualitative variables on the dependent variable may be analysed after such variables are defined as "dummy" variables (Buyukozturk, 2009). To determine whether or not to perform factor analysis, the Kaiser-Meyer-Olkin (KMO) Value and Bartlett's test of sphericity were calculated before the exploratory factor analysis. The KMO and Bartlett results are shown in Appendix 1.

KMO values over 0.50 (KMO=0.90, p<0.01) indicate that factor analysis sampling was appropriate. Bartlett's test of sphericity was significant at (104.010,774) p<.01, showing that the tool can be differentiated into factor structures. Using the t-test for the reliability of the meaningfulness of the median of the top 27% and bottom 27% groups were determined. While there are fourteen determinants in the graph with a high acceleration, the general trend of the graph in the fifteenth and subsequent determinants are horizontal, and they have no significant declining trend (appendix 2). Analyses of the factors were done with 14 determinants and 71 items. The total variance of the factors was 61.17%. Furthermore, those item loads larger than 0.44 were chosen and included in the classification. Any item was not excluded from the classification of the main determinants because it was not a disassociated item and the remaining 71 items were loaded on the 14 determinants labelled;

Determinant 1 - Extra-Curricular Aktivities (ECA) (1, 2, 3, 4, 5, 6, 7, 8 and 9)

Determinant 2 – Teacher's Teaching Skills (TTS) (10, 11, 12, 13, 14, 15, 16 and 17)

Determinant 3 – Attitude toward Science (ATSci) (18, 19, 20, 21 and 22)

Determinant 4 - Attitude towards School (ATSch) (23, 24, 25, 26, 27 and 28)

Determinant 5- Teacher's Feedback for Academic Development of Student (TFADS) (29, 30, 31, 32, 33)

Determinant 6 - Attitude of Teachers towards the student (ATTS) (34, 35, 36, 37, 38 and 39)

Determinant 7 – Interest in Science Content Knowledge (ISCK) (40, 41, 42, 43 and 44)

Determinant 8 - Test Anxiety of Student (TAS) (45, 46, 47, 48 and 49)

Determinant 9 - Education Support of Parents (ESP) (50, 51, 52 and 53)

Determinant 10-Teacher's Disposition to Teaching (TDT) (54, 55, 56 and 57)

Determinant 11- Teamwork (TW) (58, 59, 69 and 61)

Determinant 12- Class Management (CM) (62, 63 and 64)

Determinant 13- Socio Economic Characteristics (SEC) (65, 66, 67, 68 and 69)

Determinant 14- Educational Level of Parents (ELP) (70 and 71)

Data Analysis

While main determinants were classified, exploratory factor analysis was tested. Moreover, the linear trend method was used to complete the missing data. Multiple regression analysis was used in one of the patterns that examine the effect of the measurable and non-measurable independent variables on the dependent variable (Buyukozturk, 1997). However, this does not mean the causality of relations (Tabachnick and Fidell, 2015). Standard regression analysis and Stepwise regression analysis were tested by the measurement of the variance factors affecting environmental literacy.

It is also examined that the correlation between independent variables and dependent variable are not higher than 0.80. It is stated that regression analysis can be performed when the correlation value is not higher than 0.80 (Buyukozturk, 2009). Moreover, when the assumptions of linearity and normality are examined, it is seen that the maximum value of The Variance Inflation Factor (VIF) values in German students is between 1.03 and 1.68 (VIF value), between 1.04 and 1.41 for Estonian students and between 1.03 and 1.45 for Singaporean students. The VIF is widely used measures of the degree of multi-collinearity in a regression model (O'Brien, 2007). $1 < VIF \leq 5$ indicates moderate multi-link and the model correction is not required (Karagoz, 2016). In addition to the values of the sequential residual terms must be independent from each other and it is examined that whether there is an autocorrelation between the values with Durbin-Watson test (Yavuz, 2009). It is also expected that the Durbin-Watson coefficient of the regression analysis is between 1.5 and 2.5. (Karagoz, 2016). It is seen that the model established for Germany is 2,00, while the model established for Estonia is 1,89, and for Singapore 1,92. On the other hand, the P-P plot is theory-driven graphical methods for testing normality (Park, 2006). The results obtained in Appendix 3 and P-P Plot images show that the regression analysis is normally distributed. Moreover, according to scatter plots examined, it is accepted that if the error terms (residuals) on the graph randomly scattered around zero, it shows that the variance in the error terms is constant (Rudy, 2011; Sezer, 2016). The possible relationship between continuous dependent and independent variables should always be based on scatter plot (Schneider, Hommel and Blettner, 2010). Therefore, the results of the scatter graph images show that the regression analysis is linearity and the variance in the error terms is constant.

Results and Comments

Findings obtained from this research are shared in separate sections.

Findings related to German students

Table 1: Regression analysis of environmental literacy of German students

Determinant	B	Std. Er.	Beta	T	P	Zero-Order	Partial
Constant	2,064	,121		17,072	,000	-	-
Extra-Curricular Activities	,123	,013	,202	9,393	,000	,315	,191
Teacher’s Teaching Skills	,129	,016	,158	7,877	,000	,267	,161
Attitude toward Science	-,026	,009	-,068	2,852	,004	-,253	-,059
Attitude towards School	,026	,022	,022	1,178	,239	,038	,024
Teacher’s Feedback for Academic Development of Student	-,047	,011	-,093	4,387	,000	-,267	-,091
Attitude of Teachers towards the student	,000	,011	,001	,029	,977	,062	,001
Interest in Science Content Knowledge	-,049	,025	-,042	1,952	,051	-,178	-,040
Test Anxiety of Student	,033	,009	,070	3,657	,000	,117	,076
Education Support of Parents	-,032	,011	-,054	2,811	,005	-,111	-,058
Teacher's Disposition to Teaching	-,062	,010	-,133	6,275	,000	-,280	-,129
Teamwork	-,005	,010	-,010	,539	,590	-,038	-,011
Class Management	,005	,009	,012	,608	,543	-,052	,013
Socio Economic Characteristics	,023	,015	,030	1,583	,114	,004	,033
Educational Level of Parents	-,003	,008	-,008	,436	,663	,015	-,009
R= 0.46, R2 = 0.21, F(14, 2319) = 43,34, p < .01							

As shown in Table 1, it was found that there is a meaningful relationship between total variance of 14 predictive variables and environmental literacy ($F(14, 2319) = 43{,}34$ $p < .01$). These variables clarified for approximately the 21% of the total variance in environmental literacy, the dependent variable. While the main determinants influencing environmental literacy positively in Germany are "extra-curricular activities" and "teacher's teaching skills"; the "teacher's disposition to teaching" determinant is the most negative determinant.

According to stepwise regression analysis, the mathematical model is demonstrated below: (appendix 4):

$$\text{Environmental Literacy} = 2{,}166 + {,}13*(ECA) - {,}06*(TDT) + {,}13*(TTS) - {,}05*(TFADS) - {,}03*(ATSci) + {,}03*(TAS) - {,}03*(ESP)$$

Seven steps have been included in the multiple regression analysis; however, 19% of 20% of the total variance in environmental literacy describe the variables in the first 4 steps. "Extra-curricular activities" are the predictor variables that provide the highest contribution to the regression equation and the explanation rate is 10%.

Findings related to Singaporean students

Table 2: Regression analysis of environmental literacy of Singaporean students

Determinant	B	Std. Er.	Beta	T	P	Zero-Order	Partial
Constant	2,062	,080		25,887	,000	-	-
Extra-Curricular Activities	,140	,008	,276	18,273	,000	,356	,266
Teacher’s Teaching Skills	,092	,013	,101	7,252	,000	,155	,109
Attitude toward Science	-,010	,007	-,021	-1,320	,187	-,224	-,020
Attitude towards School	,061	,015	,056	4,121	,000	,062	,062
Teacher’s Feedback for Academic Development of Student	-,047	,006	-,113	-7,307	,000	-,263	-,110
Attitude of Teachers towards the student	-,003	,007	-,006	-,418	,676	,061	-,006
Interest in Science Content Knowledge	-,038	,018	-,032	-2,117	,034	-,156	-,032
Test Anxiety of Student	,035	,007	,072	5,184	,000	,108	,078
Education Support of Parents	-,018	,008	-,035	-2,407	,016	-,132	-,036
Teacher's Disposition to Teaching	-,049	,007	-,117	-7,500	,000	-,249	-,113
Teamwork	-,004	,007	-,009	-,630	,529	-,061	-,010
Class Management	-,020	,006	-,045	-3,156	,002	-,115	-,048
Socio Economic Characteristics	,008	,010	,012	,872	,383	-,022	,013
Educational Level of Parents	,007	,005	,020	1,434	,152	,063	,022
R= 0.45, R2 = 0.21, F(14, 4378) = 80,54, p < .01							

Table 2 shows that, there is a meaningful relationship between total variance of 14 predictive variables and environmental literacy ($F(14, 4378) = 80{,}54$ $p < .01$). These variables clarified for approximately the 21% of the total variance in environmental literacy, a dependent variable. Determinants that affect environmental literacy positively in Singaporean students are "extra-curricular activities", "teacher's teaching skills" and "attitude towards school". However, the most negative determinants are the "teacher's disposition to teaching", "teacher's feedback for academic development of student" and "interest in science content knowledge". According to stepwise regression analysis, the mathematical model is demonstrated below: (appendix 5):

Environmental Literacy = 2,053 + ,14*(ECA) - ,05*(TDT) + ,09*(TTS) - ,05*(TFADS) + ,04*(TAS) + ,06*(ATSch) - ,02* (CM) - ,05*(ISCK) - ,02*(ESP)

9 steps are included in the multiple regression analysis; however, 18% of 20% of the total variance in environmental literacy reveals variables in the first 3 steps. The "extra-curricular activities" that provide the highest contribution to the regression equation and the explanatory rate is 13%.

Findings related to Estonian students

Table 3: Regression analysis of environmental literacy of Estonian students

Determinant	**B**	**Std. Er.**	**Beta**	**T**	**P**	**Zero-Order**	**Partial**
Constant	1,793	,082		21,861	,000		
Extra-Curricular Activities	,165	,008	,302	19,733	,000	,318	,286
Teacher's Teaching Skills	,103	,011	,134	9,149	,000	,186	,137
Attitude toward Science	,040	,007	,088	5,359	,000	-,050	,081
Attitude towards School	,054	,016	,048	3,354	,001	,074	,051
Teacher's Feedback for Academic Development of Student	-,044	,007	-,098	-6,264	,000	-,213	-,094
Attitude of Teachers towards the student	,015	,008	,029	1,975	,048	,013	,030
Interest in Science Content Knowledge	,050	,018	,042	2,713	,007	-,012	,041
Test Anxiety of Student	,030	,007	,061	4,248	,000	,084	,064
Education Support of Parents	-,010	,008	-,019	-1,309	,191	-,055	-,020
Teacher's Disposition to Teaching	-,032	,007	-,072	-4,528	,000	-,167	-,068
Teamwork	-,019	,008	-,036	-2,519	,012	-,058	-,038
Class Management	,010	,006	,022	1,535	,125	,014	,023
Socio Economic Characteristics	-,022	,010	-,032	-2,246	,025	-,061	-,034
Educational Level of Parents	-,010	,007	-,019	-1,337	,181	-,027	-,020
R= 0.41, R2 = 0.16, F(14, 4370) = 61,17, p < .01							

As Table 3 presents, there is a meaningful relationship between total variance of 14 predictive variables and environmental literacy ($F(14, 4379) = 61{,}17 \quad p < .01$). These variables clarified for approximately the 16% of the total variance in environmental literacy, a dependent variable. One of the main determinants that affect environmental literacy positively in Estonian students is "extra-curricular activities" and the other one is "teacher's teaching skills". "Teacher feedback for academic development of student" is the most important negative determinant.

According to stepwise regression analysis, the mathematical model is demonstrated below: (appendix 6):

Environmental Literacy = 1,799 + ,16*(ECA) + ,11*(TTS) - ,05*(TFADS) +,04*(ATSci) - ,03*(TDT) + ,03*(TAS) + ,05*(ATSch) - ,02*(TW) + ,05*(ISCK) - ,02*(SEC)

There are 10 steps involved in multiple regression analysis; however, 15% of the 16% of the total variance in environmental literacy are variable in the first 4 steps. "Extra-curricular activities" are the predictor variables that provide the highest contribution to the regression equation and the explanation rate is 10%.

Discussion

In the light of selected determinants, it is concluded that all three countries have a low but significant relationship between environmental literacy and variables. Although for Estonian students there seems various determinants that affect on environmental literacy, it is also seen that the total variance ratio is lower than the other two countries. Although the determinant affecting environmental literacy is few in German students, the variance rate is about the same as that of Singaporean students. It is the determinant "extra-curricular activities" that is associated with the curriculum that has the most significant positive impact on environmental literacy among all three countries' students. The determinant "extra-curricular activities" has the greatest positive impact on environmental literacy of German students. In a similar study, it is mentioned that out-of-school activities have an important effect on the students' physical success (Adeyemo, 2010). However, Sayin and Gelbal (2014) found that participation in social activities was the least important factor in the success of students. In analysing PISA 2006 data, Yildirim's (2012) identified that family characteristics as the most important factor of the educational qualities of Turkey. In Sarier's (2016) study, the most important factors affecting the academic success of students are found to be socio-economic status, self-efficacy and motivation. On the other hand, in Farooq's et al., studies (2011), socio-economic characteristics and parents' education have a significant effect on students' overall academic achievement. Moreover, in another study, Kaya and Elster (2017a) mentioned that there is a significant relationship between EL and SEC. However, in this research, "socio-economic characteristics" determinant is not a meaningful determinant in environmental literacy in Germany and Singapore. Furthermore, "educational level of parents" determinant is not the significant determinant for the environmental literacy in three countries.

When the teacher-derived factors are examined, the factor "teacher's teaching skills" has positive and significant effect in all three countries. However, "teacher's disposition to teach" has a significant negative impact. "Teacher's feedback for academic development of student" is found to be another teacher-driven factor that has a significant impact on environmental literacy in the negative direction in all three countries. Another similar study was stated that teacher support is influential on achievement performance (Becker and Luthar, 2002).

According to Akiri (2013), quality teachers produced better performing students; however, the observed differences in students' performance were statistically not significant. However, Sayin and Gelbal (2014) studied with university candidates and found that the most important factor in the success of the students was teacher competencies and the teaching strategy and method.

With the help of the "Test Anxiety of student" factor which is one of the student-derived factor, students are having a positive effect on environmental literacy. When an anxiety is at a certain level, it can have a positive effect. While the anxiety rises, it can turn into a negative effect. Since, test anxiety causes a negative effect on academic achievement in different studies (Rana and Mahmood, 2010; Olatoye, 2009; Yildirim, 2000). The other student-generated factor "attitude towards the science" has a negative impact on environmental literacy of students in both Germany and Singapore; students have a positive impact on environmental literacy in Estonia. This effect is meaningful for German and Estonian students; but it does not seem to make sense for Singaporean students. In her studies (2009, 2011), Anil used PISA 2006 data to identify students' "attitudes toward science" as one of the most predictive variables of science achievement. Another study indicates that there is a meaningful and positive relationship between attitudes towards science and technology, and academic achievement (Akpınar et al., 2009; Ali, Iqbal and Akhtar, 2015). Besides, it is stated that there is a strong relationship between attitude towards science and achievement (Craker, 2006). Similar results have been obtained in studies conducted in different interdisciplinary fields. In one of these, it is seen that there is a relationship between the attitude towards the course and mathematics success (Savas, Tas and Duru, 2010).

Another factor which is "attitude towards school", has a positive impact on the environmental literacy of students from all three countries. This effect has been achieved for Estonian and Singaporean students but it is meaningless for German students. In Moè, Pazzaglia, Tressoldi and Toso's work (2009), they point out that the relationship between emotional motivation variables and academic achievement is the role of the attitude toward the arrow. Moreover, Verešová and Malá (2016) mention that ‘the attitude toward school and learning’ is an important predictor of achievement. Therefore, the more positive is ‘the attitude towards school and learning of students, the more positive is academic achievement at the end of the school year. Another study reveals that attitudes toward school influence achievement, however, only indirectly (Abu-Hilal, 2000).

Conclusions and Recommendations

The findings demonstrate the importance of “extra-curricular activities" to train more qualified environmental literate individuals. Therefore, more extra-curricular activities such as stimulating natural phenomena in computer programs, participation in science clubs especially ecology organizations, field trips and excursions that promote the awareness and the connectedness to the nature and the environment should be included in formal education. In addition, these activities should support formal education and be implemented and encouraged in a planned manner as a complement to each other.

In addition, support should be provided for the development of teacher training skills for science teachers and teacher candidates. Examples for skills and competences that should be trained are how to give feedback for the academic development of the student, how teamwork should be implemented, and what to look for an effective classroom management.

In addition, practical EE could be offered through in-service and pre-service education. In this way, teachers' tendency (teacher's disposition to teach) towards teaching can be improved. In this process, teachers and teacher candidates should be encouraged to use a constructivism approach in teaching and learning and ensure an effective students' participation in this process.

On the other hand, the reasons for the positive effects of the attitudes of students in Estonia towards the school, science and science content knowledge to environmental literacy should be investigated in more detail. SE applications should be investigated which lead to positive attitudes towards students in education. In this area, Estonia's education system can lead to improved environmental literacy for students by identifying good examples of the SE system in particular.

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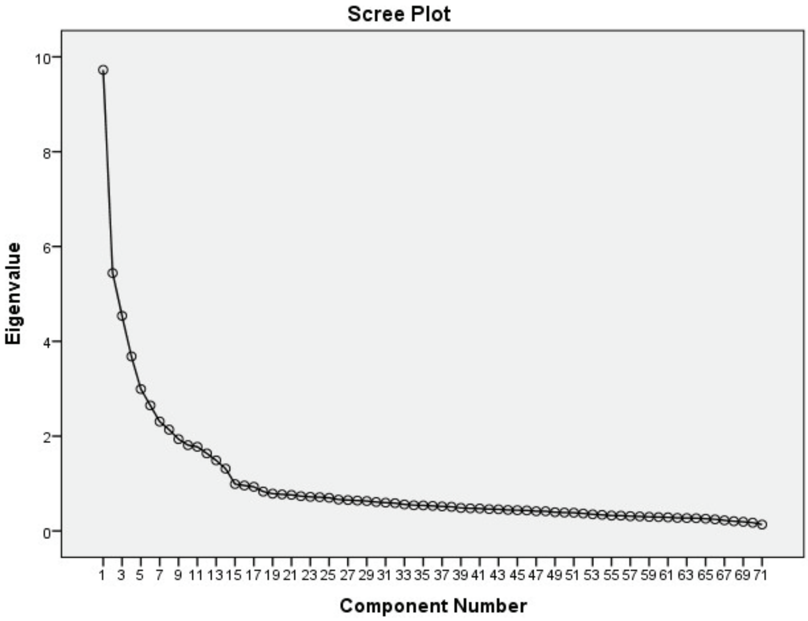
Appendixes:

Appendix 1: Kaiser-Meyer-Olkin and Bartlett’s Test of Sphericity results

Kaiser-Meyer-Olkin Value	,90	
Bartlett’s Test Value		104.010,774
		2485
	p	,00

* p<,01

Appendix 2: Graphic of Eigenvaluse



Appendix 3: P-P Plot of Regression

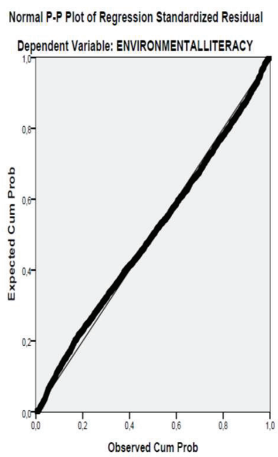


Figure A: P-P Plot of Regression (Germany)

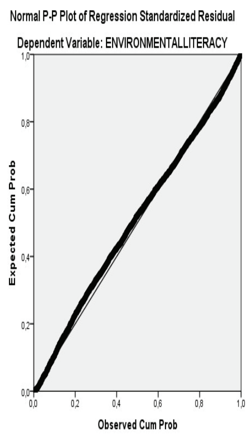


Figure B: P-P Plot of Regression (Singapore)

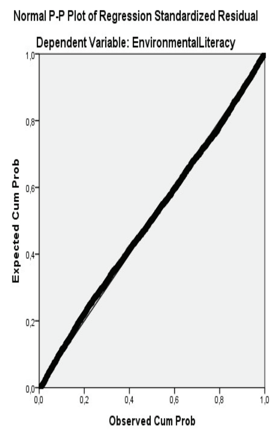


Figure C: P-P Plot of Regression (Estonia)

Appendix 4.a: Stepwise Regression Analysis of Environmental Literacy for Germany

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
1	(Constant)	1,881	,042		44,655	,000	,315	,099
	ECA	,192	,012	,315	16,049	,000		
2	(Constant)	2,222	,049		44,999	,000	,393	,154
	ECA	,169	,012	,279	14,461	,000		
	TDT	-,111	,009	-,237	-12,267	,000		
3	(Constant)	1,856	,063		29,687	,000	,429	,184
	ECA	,161	,012	,265	13,957	,000		
	TDT	-,087	,009	-,186	-9,449	,000		
	TTS	,148	,016	,181	9,247	,000		
4	(Constant)	1,979	,068		29,202	,000	,437	,191
	ECA	,150	,012	,246	12,719	,000		
	TDT	-,073	,010	-,156	-7,550	,000		
	TTS	,136	,016	,166	8,381	,000		
	TFADS	-,049	,011	-,096	-4,585	,000		
5	(Constant)	2,129	,076		28,058	,000	,445	,198
	ECA	,126	,013	,208	9,817	,000		
	TDT	-,065	,010	-,138	-6,549	,000		
	TTS	,135	,016	,165	8,366	,000		
	TFADS	-,050	,011	-,099	-4,728	,000		
	ATSci	-,035	,008	-,092	-4,333	,000		

Appendix 4.b: Stepwise Regression Analysis of Environmental Literacy for Germany

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
6	(Constant)	2,055	,079		26,110	,000	,449	,202
	ECA	,125	,013	,205	9,687	,000		
	TDT	-,063	,010	-,135	-6,401	,000		
	TTS	,135	,016	,166	8,411	,000		
	TFADS	-,051	,011	-,100	-4,780	,000		
	ATSci	-,032	,008	-,084	-3,957	,000		
	TAS	,031	,009	,065	3,485	,001		
7	(Constant)	2,166	,089		24,435	,000	,452	,204
	ECA	,125	,013	,205	9,714	,000		
	TDT	-,062	,010	-,133	-6,339	,000		
	TTS	,131	,016	,160	8,082	,000		
	TFADS	-,049	,011	-,097	-4,647	,000		
	ATSci	-,031	,008	-,083	-3,906	,000		
	TAS	,030	,009	,064	3,392	,001		
	ESP	-,030	,011	-,051	-2,716	,007		

Appendix 5.a: Stepwise Regression Analysis of Environmental Literacy for Singapore

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
1	(Constant)	1,975	,024		82,194	,000	,356	,127
	ECA	,181	,007	,356	25,246	,000		
2	(Constant)	2,258	,030		74,248	,000	,409	,167
	ECA	,167	,007	,328	23,605	,000		
	TDT	-,086	,006	-,204	-14,657	,000		
3	(Constant)	2,027	,042		48,276	,000	,423	,179
	ECA	,166	,007	,326	23,621	,000		
	TDT	-,078	,006	-,185	-13,234	,000		
	TTS	,100	,013	,110	7,933	,000		
4	(Constant)	2,128	,044		48,662	,000	,436	,190
	ECA	,154	,007	,303	21,531	,000		
	TDT	-,058	,006	-,139	-9,131	,000		
	TTS	,099	,013	,109	7,893	,000		
	TFADS	-,049	,006	-,118	-7,682	,000		
5	(Constant)	2,035	,047		43,220	,000	,442	,195
	ECA	,151	,007	,298	21,240	,000		
	TDT	-,058	,006	-,137	-9,067	,000		
	TTS	,097	,013	,106	7,715	,000		
	TFADS	-,049	,006	-,117	-7,612	,000		
	TAS	,035	,007	,071	5,208	,000		
6	(Constant)	1,877	,061		30,700	,000	,445	,198
	ECA	,149	,007	,294	20,957	,000		
	TDT	-,058	,006	-,137	-9,051	,000		
	TTS	,097	,012	,107	7,770	,000		
	TFADS	-,049	,006	-,117	-7,654	,000		
	TAS	,038	,007	,078	5,709	,000		
	ATSch	,060	,015	,055	4,029	,000		

Appendix 5.b: Stepwise Regression Analysis of Environmental Literacy for Singapore

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
7	(Constant)	1,942	,063		30,731	,000	,448	,201
	ECA	,149	,007	,294	20,988	,000		
	TDT	-,054	,006	-,127	-8,313	,000		
	TTS	,095	,012	,105	7,643	,000		
	TFADS	-,048	,006	-,116	-7,594	,000		
	TAS	,035	,007	,072	5,265	,000		
	ATSch	,062	,015	,058	4,210	,000		
	CM	-,024	,006	-,055	-3,955	,000		
8	(Constant)	2,001	,066		30,271	,000	,450	,203
	ECA	,144	,007	,284	19,763	,000		
	TDT	-,052	,006	-,124	-8,130	,000		
	TTS	,096	,012	,105	7,680	,000		
	TFADS	-,048	,006	-,116	-7,585	,000		
	TAS	,035	,007	,071	5,145	,000		
	ATSch	,060	,015	,055	4,051	,000		
	CM	-,023	,006	-,051	-3,642	,000		
	ISCK	-,050	,017	-,042	-3,013	,003		
9	(Constant)	2,053	,069		29,854	,000	,452	,204
	ECA	,143	,007	,283	19,628	,000		
	TDT	-,051	,006	-,120	-7,789	,000		
	TTS	,093	,013	,102	7,424	,000		
	TFADS	-,047	,006	-,113	-7,421	,000		
	TAS	,035	,007	,072	5,219	,000		
	ATSch	,062	,015	,057	4,176	,000		
	CM	-,021	,006	-,047	-3,369	,001		
	ISCK	-,046	,017	-,039	-2,747	,006		
	ESP	-,020	,007	-,038	-2,733	,006		

Appendix 6.a: Stepwise Regression Analysis of Environmental Literacy for Estonia

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
1	(Constant)	2,069	,026		78,718	,000	,318	,101
	ECA	,174	,008	,318	22,199	,000		
2	(Constant)	1,809	,034		53,625	,000	,360	,130
	ECA	,169	,008	,309	21,879	,000		
	TTS	,130	,011	,169	12,000	,000		
3	(Constant)	1,993	,040		49,584	,000	,378	,143
	ECA	,153	,008	,280	19,409	,000		
	TTS	,117	,011	,152	10,752	,000		
	TFADS	-,054	,006	-,121	-8,278	,000		
4	(Constant)	1,837	,048		38,219	,000	,387	,150
	ECA	,167	,008	,306	20,342	,000		
	TTS	,121	,011	,158	11,174	,000		
	TFADS	-,057	,006	-,129	-8,847	,000		
	ATSci	,039	,007	,087	5,853	,000		
5	(Constant)	1,899	,050		38,032	,000	,392	,154
	ECA	,168	,008	,307	20,482	,000		
	TTS	,111	,011	,145	10,043	,000		
	TFADS	-,046	,007	-,104	-6,643	,000		
	ATSci	,044	,007	,099	6,554	,000		
	TDT	-,032	,007	-,071	-4,467	,000		
6	(Constant)	1,839	,052		35,280	,000	,396	,157
	ECA	,167	,008	,305	20,374	,000		
	TTS	,108	,011	,140	9,695	,000		
	TFADS	-,046	,007	-,103	-6,606	,000		
	ATSci	,047	,007	,105	6,967	,000		
	TDT	-,033	,007	-,073	-4,600	,000		
	TAS	,027	,007	,056	3,985	,000		
7	(Constant)	1,706	,067		25,347	,000	,398	,158
	ECA	,163	,008	,299	19,790	,000		
	TTS	,108	,011	,141	9,775	,000		
	TFADS	-,045	,007	-,102	-6,538	,000		
	ATSci	,047	,007	,105	6,978	,000		
	TDT	-,033	,007	-,073	-4,621	,000		
	TAS	,031	,007	,063	4,437	,000		
	ATSch	,050	,016	,044	3,108	,002		

Appendix 6.b: Stepwise Regression Analysis of Environmental Literacy for Estonia

Model	Factor	B	Std. Er.	Beta	t	p	R	R^2
8	(Constant)	1,754	,070		25,177	,000	,400	,160
	ECA	,163	,008	,299	19,798	,000		
	TTS	,107	,011	,140	9,672	,000		
	TFADS	-,044	,007	-,099	-6,341	,000		
	ATSci	,047	,007	,105	6,969	,000		
	TDT	-,032	,007	-,072	-4,533	,000		
	TAS	,032	,007	,066	4,624	,000		
	ATSch	,052	,016	,045	3,203	,001		
	TW	-,020	,007	-,037	-2,625	,009		
9	(Constant)	1,733	,070		24,737	,000	,401	,161
	ECA	,165	,008	,301	19,933	,000		
	TTS	,107	,011	,140	9,673	,000		
	TFADS	-,044	,007	-,099	-6,366	,000		
	ATSci	,040	,007	,089	5,438	,000		
	TDT	-,033	,007	-,073	-4,622	,000		
	TAS	,032	,007	,065	4,576	,000		
	ATSch	,052	,016	,046	3,215	,001		
	TW	-,020	,007	-,038	-2,704	,007		
	ISCK	,049	,018	,041	2,673	,008		
10	(Constant)	1,799	,076		23,628	,000	,403	,162
	ECA	,164	,008	,300	19,836	,000		
	TTS	,106	,011	,138	9,590	,000		
	TFADS	-,045	,007	-,100	-6,421	,000		
	ATSci	,039	,007	,087	5,371	,000		
	TDT	-,032	,007	-,071	-4,501	,000		
	TAS	,031	,007	,064	4,496	,000		
	ATSch	,051	,016	,045	3,190	,001		
	TW	-,019	,007	-,036	-2,588	,010		
	ISCK	,051	,018	,043	2,771	,006		
	SEC	-,021	,010	-,031	-2,203	,028		

2.1.1.4. Dimensions Affecting Environmental Literacy, and Environmental Perceptions Influencing Science Literacy

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Abstract

One of the main aims of this paper is to determine the dimensions (effects of family, teacher, student, and teaching) that influence the environmental literacy. Moreover, another purpose is to determine the effects of environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) on science literacy of fifteen-years-old students in Germany. The sample consisted of 6.500 German students. The relational model, which is one of the quantitative research approaches, has been adopted in this study. The results show that 'the dimension of the teacher', one of the dimensions included in the first model, has the most negatively effect on environmental literacy; but, the dimension of 'effect of teaching' has the positively effect on environmental literacy. In addition, in the second model, it is obtained results that students of environmental awareness and optimism have a positive effect on the science literacy; but environmental responsibility has a negative effect on it. For this reason, while developing environment-related

curriculums, it should be supported students to gain more responsible behaviors towards the environment. Enhancing the environmental responsibility of the students might contribute to both environmental literacy and science literacy.

Keywords: Environmental Literacy, Science Literacy, PISA, Environmental Perceptions

1. Introduction

The main purpose of this study is to elucidate the reflection of education for sustainable development (ESD) applied in Germany between 2005 and 2014 on both the environmental and science literacy (SL). Through ESD, it is stated that when students obtain knowledge about the environment, they might be critical thinkers and develop socially critical learning and problem-solving skills (Peden, 2008). This education was planned to make both national and international assessments on environmental literacy (Hollweg, Taylor, Bybee, Marcinkowski, McBeth & Zoido, 2011). To increase the quality of sustainable development in the future, outcomes of the environmental literacy especially environmental perceptions has an important role. Therefore, this study aims to determine both the dimensions (family, teacher, learner and teaching) that influence the environmental literacy and the effect of environmental perceptions on SL.

1.1 The Education for Sustainable Development

Education for sustainable development have a more significant role in the future social transformation for people to survive their lives (Peters and Gonzalez-Gaudiano 2008). The education for sustainable development is a way to be pursued for sustainable future (Tabucanon, 2010). In 2005, the UNESCO launched its Decade of Education for Sustainable

Development (2005-2014) (UNESCO, 2005b). In this decade, educational institutions in Germany increased their efforts to educate students for a more sustainable future (Kaya and Elster, 2017a). Through education for sustainable development, individuals benefit from education and gain the values and behaviors that are necessary in their lives for a more qualified social transformation and sustainable future (UNESCO, 2005a). Furthermore, education for sustainable development focuses on the competencies required to transform social relations, economics and the management of natural resources (Dannenberg and Grapentin, 2016). Thus, education for sustainable development, that integrates economic growth, social development, and environmental protection, is aimed at improving the quality of life of individuals, both now and in the future (UNESCO, 2005b).

1.2. Science and Environmental Literacy

SL is a one of some main concepts of the science education (SE). According to National Science Education Standards, 'the scientific literate individual can ask, find, or determine answers to questions raised by curiosity about daily life. The individual has the skill to describe, explain, and predict natural phenomena (NRC, 1996)'. This concept has continued to be relevant in SE because of its openness to change and development.

On the other hand, environmental literacy is a more specific concept than SL. According to PISA results, environmental literacy has three categories as responsibility and optimism towards the environment (Kaya and Elster, 2017a), and the development of environmental behavior (Kaya & Elster, 2017b). Moreover, environmental perceptions are paramount elements of environmental literacy. It is stated that there is a positive correlation between the 'responsibility and awareness towards the environment' in the definition of environmental literacy and 'optimism towards the environment' (Kaya & Elster, 2018a). To educate more optimistic students for a more sustainable future and development, both the science and the environment literacy of students should be developed. For this reason, the influence and interrelationship of these two concepts in SE should be taken into consideration.

1.3. Purpose of the Research

Traditional approaches to EE seem to be ineffectual in overcoming the environmental problems (Çimen & Yılmaz, 2014). Therefore, education for sustainable development, which is important for a sustainable future and carries the traces of transformative education, has been implemented between 2005 and 2014. Education for sustainable development assures the sustainable life opportunity, aspirations and futures for youth (Pavlova, 2013). Moreover, economic development is the basis of human development in education for sustainable development (Tanriverdi, 2009). Therefore, the importance of environment-oriented education for sustainable development is expected to increase in the future. Thus, outcomes of the education for sustainable development (between 2005 to 2014) should be assessed. Moreover, the disclosure of the effect of environmental perceptions on the SL can lead to a more qualified implementation of education for sustainable development in the future.

1.4. Design of Research

For a more sustainable future and development, more qualified environmentally literate individuals are needed with the contribution of SE. For this reason, it is necessary to determine the dimensions that affect education for sustainable development through environmental literacy. Moreover, not only schools including teachers and teaching are responsible for the educating of more qualified individuals, but also the students themselves, and their families are responsible for more sensitive, responsible, and aware individuals in respect to the environment. Focusing on these aspects might also allow to promote more qualified solutions for a sustainable development and future.

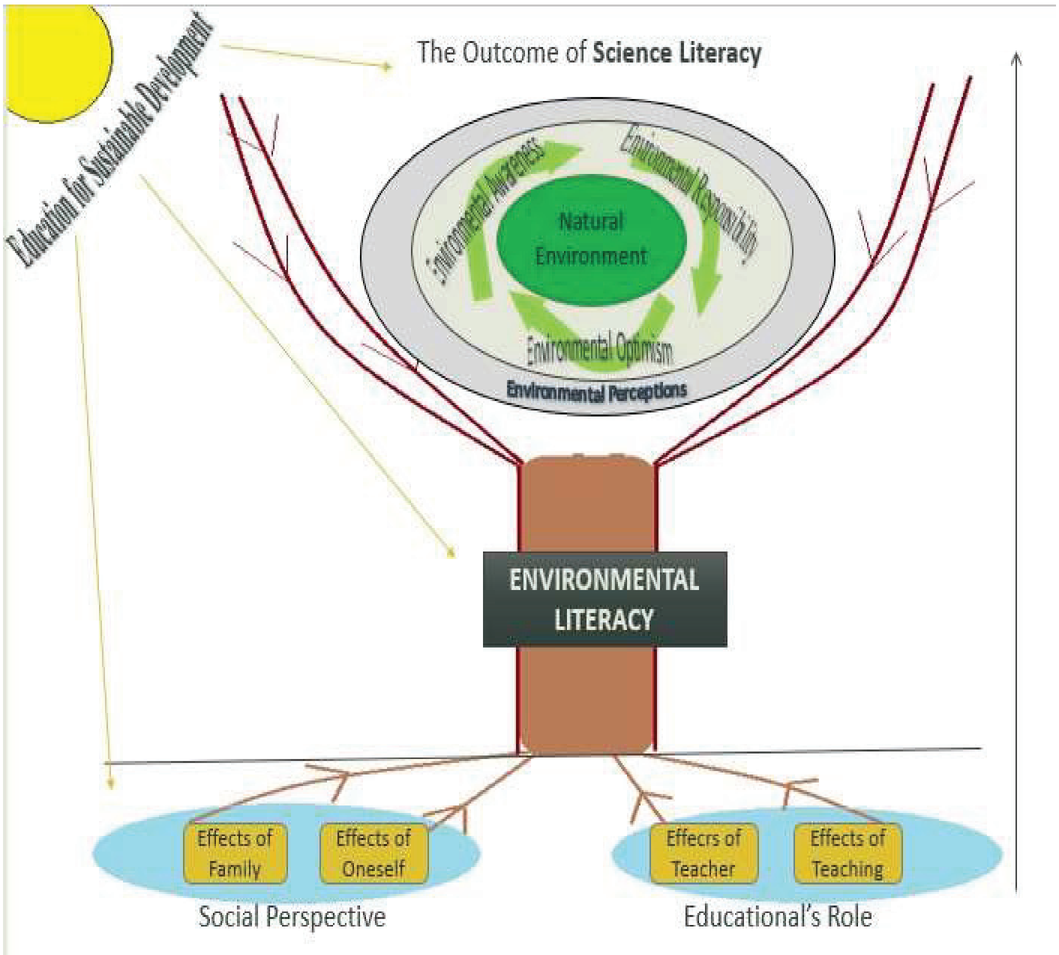

Figure 1: Design of Research

The development of literacy, especially the development of environmental literacy, is like the development of a seed. There are several factors that affect the development of the seed as well as the factors (such as family, teacher, learner and teaching etc…) that affect the development of environmental literacy. The most environment constituents that are effective on plants should be considered together, otherwise, the deficiency of one fundamental component can affect the development of the plant (Easton and Glauer, 2015). Similarly, the environmental factors that affect the quality of the learner should be taken into the consideration together. A more qualified recommendation can be put on this view. In general, the essential components influencing student quality are the learning social environment, and the formal education in which it is being trained. Two important educators in the life of a learner are their families and their teachers (DCSF, 2009). Both have an important role at each stage of education (Scottish Executive, 2006). Moreover, the science teaching process in the school, and the student himself have an essential effect on the quality of the learners. It is also important to assess whether these paramount dimensions have a desired level of influence on the education for sustainable development. Consequently, in this study, the effects of the family, the learner, the science teacher, and teaching on the education for the sustainable development have been disclosed through environmental literacy.

On the other hand, in the light of the obtained outcome of the education for sustainable education at the end of the formal education, it is necessary to reveal the effects of environmental perceptions on the SL. These outcomes would mention whether the curriculum has helped to support the pupils with the competencies, values, citizenship responsibilities in the curricular targets (Stabback, 2016). By this means, for more sustainable development and future, researchers, policymakers, educators and teachers receive effective feedback on how to improve and teach the next generation SE. Curriculum development, teaching, assessment and learning environments should be permanently focused on educational outcomes (European Union, 2012; p. 19). Therefore, the outcome of the EDS on the SE is also the paramount element of the development of the qualified students. Education, especially 'education for Sustainable Development', is not only about being the environmental literate individual (Nayar, 2013); it also about being the successful individual in SE. In this study, the outcomes of EDS on SE were examined through SL and recommendations about the obtained results were shared in the part of the implications and recommendations.

Research Questions

In this study, one of the main aims of this paper is to determine the dimensions (effects of family, teacher, student, and teaching) that influence the environmental literacy. Moreover, another aim is to analyse the effects of environmental perceptions on SE through SL. In these regards the research questions are:

- What are the dimensions (effects of family, teacher, student, and teaching) influencing the Environmental Literacy (EL) of the German students?
- How much of the explained variance of the Environmental Literacy averages is explained by the dimensions covered in this research?
- What are the environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) influencing the SL of the German students?
- How much of the explained variance of SL averages is explained by the environmental perceptions covered in this research?

2. Research Methods and Design

In this section, the type of study, sampling, data collection and the data analysis are explained.

2.1.Type of Study

The relational model, which is one of the quantitative research approaches, has been adopted in this study. Through the relational model, it was tried to determine the dimensions (effects of family, teacher, student, and teaching) influencing the Environmental Literacy (EL) and the dimensions that related environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) influencing the SL. This empirical study is designed to provide a more successful development of SE for a more sustainable future.

Sampling

In this study, the universe was 15-years-old German students. The PISA sample selection was conducted randomly by applying the two-stage stratified sampling method (Albayrak Sarı, 2015). The sample consisted of 6.500 German students. The data obtained with the participation of students from Germany involved PISA 2015 data. It was obtained on the internet from the official PISA web site (http://www.pisa.oecd.org).

Measures and Data Tools

Two regression models are created in this study. The main purpose of the first regression model is to determine the dimensions (effects of family, teacher, student, and teaching) influencing the Environmental Literacy (EL) and to calculate the explained variance of the Environmental Literacy averages. Researchers used *Environmental Literacy Scale* developed by Kaya and Elster (2017b) to calculate students' scores in the 1st regression model. The environmental literacy scores of the students were considered as dependent variables. Moreover, the 71 items selected from the student questionnaires in the PISA data were classified categories by Kaya and Elster (2018) as 14 main factors. In this study, these factors are categorized on 4 main dimensions (effects of family, teacher, student, and teaching) as the independent variables.

The goal of the second regression model is to determine the environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) influencing the SL and to calculate the explained variance of SL averages. The SL scores were obtained from the PISA 2015 data in the 2nd regression model. The SL scores of the students were considered as dependent variables. Furthermore, the 20 items selected from the student questionnaires in the PISA data were classified on 3 main dimensions that related to environmental perceptions (environmental awareness, environmental responsibility and environmental optimism) as the independent variables.

Data Analysis

The multiple regression analysis which are standard regression analysis and Stepwise regression analysis were tested by the measurement of the variance factors affecting both environmental literacy and SL. Before the regression analysis, it was tested some assumptions (such as normality, linearity, multi-collinearity, autocorrelation etc.) by using graph images and some statistical analysis via SPSS Software to determine whether or not to perform regression analysis.

Before regression analysis, the multiple linear regression model should provide some assumptions. In this study, it is also examined that the correlation between independent variables and dependent variable are not higher than 0.80. Moreover, it is seen that the maximum value of The Variance Inflation Factor value is between 1.01 and 1.30. The Durbin-Watson coefficient is seen that the model established for model of environmental literacy is 1,95, while the model established for SL is 1,94. P-P Plot images show that the regression analysis is normally distributed.

3. Results

3.1. Results on dimensions affecting the Environmental Literacy

Table 1: Regression Analysis on the Main Dimensions on the Environmental Literacy

Determinant	B	Std. Er.	Beta	T	P	Zero-Order	Partial
Constant	2,982	,102	-	29,372	,000	-	-
Effect of Family	-,065	,019	-,07	-3,383	,000	-,048	-,070
Effect of Teacher	-,199	,024	-,17	-8,295	,000	-,191	-,169
Effect of Oneself	-,102	,023	-,09	-4,523	,000	-,149	-,093
Effect of Teaching	,127	,016	,16	7,916	,001	,176	,162
$R= 0.28$, $R^2 = 0.08$, $F_{(4,2329)} = 48,84$, $p < .01$							

As shown in Table 1, it was found that there is a meaningful relationship between total variance of 4 predictive variables and environmental literacy ($F(4, 2329) = 48,84$ $p < .01$).

These variables clarified for approximately the 8% of the total variance in environmental literacy, the dependent variable.

Table 2: Stepwise Regression Analysis on the Main Dimensions on the Environmental Literacy

Model	Determinant	B	Std. Er.	Beta	t	P	R	R^2
1	(Constant)	3,045	,053	-	57,079	,000	,191	,036
	Effect of Teacher	-,226	,024	-,19	-9,37	,000		
2	(Constant)	2,599	,075	-	34,851	,000	,255	,065
	Effect of Teacher	-,219	,024	-,18	-9,184	,000		
	Effect of Teaching	,133	,016	,17	8,439	,000		
3	(Constant)	2,807	,088	-	32,037	,000	,270	,073
	Effect of Teacher	-,200	,024	-,17	-8,310	,000		
	Effect of Teaching	,121	,016	,15	7,576	,000		
	Effect of Oneself	-,101	,023	-,09	-4,477	,000		
4	(Constant)	2,982	,102	-	29,372	,000	,278	,077
	Effect of Teacher	-,199	,024	-,17	-8,295	,000		
	Effect of Teaching	,127	,016	,16	7,916	,000		
	Effect of Oneself	-,102	,023	-,09	-4,523	,000		
	Effect of Family	-,065	,019	-,07	-3,383	,000		

According to stepwise regression analysis, the mathematical model was as below (Table 2):

Environmental Literacy = 2,982 - ,20*(Effect of Teacher) + ,13*(Effect of Teaching) -,10*(Effect of Oneself) - ,07*(Effect of Family)

The main dimension negatively influencing environmental literacy was "teacher"; the "teaching" was the most positive dimension.

3.2. Results on Environmental Perceptions on Science Literacy

Table 3: Regression Analysis on the Effect of Environmental perceptions on SL

Determinant	B	Std. Er.	Beta	t	P	Zero-Order	Partial
Constant	415,665	13,829	-	30,058	,000	-	-
Environmental Awareness	51,630	2,859	,347	18,061	,000	,440	,326
Environmental Optimism	12,778	3,580	,061	3,569	,000	,106	,068
Environmental Responsibility	-26,120	2,673	,186	-9,773	,000	-,342	-,184
R= 0.47, $R^2 = 0.22$, $F_{(3,2729)} = 261,57$, $p < .01$							

As shown in Table 3, it was found that there is a meaningful relationship between total variance of 3 predictive variables and SL (F(3, 2729) = 261,57 p < .01). These variables clarified for approximately the 22% of the total variance in SL, the dependent variable.

Table 4: Stepwise Regression Analysis on the Effect of Environmental Perceptions on SL

Model	Determinant	B	Std. Er.	Beta	t	P	R	R^2
1	(Constant)	348,17	7,52		46,304	,000	,440	,194
	Environmental Awareness	65,50	2,55	,440	25,664	,000		
2	(Constant)	439,27	12,17		36,091	,000	,468	,219
	Environmental Awareness	53,43	2,82	,359	18,946	,000		
	Environmental Responsibility	25,11	2,66	-,179	-9,428	,000		
3	(Constant)	415,67	13,83		30,058	,000	,472	,223
	Environmental Awareness	51,63	2,86	,347	18,061	,000		
	Environmental Responsibility	-26,12	2,67	,186	-9,773	,000		
	Environmental Optimism	12,78	3,58	,061	3,569	,000		

According to stepwise regression analysis, the mathematical model was as below (Table 4):

$$\textit{Science Literacy} = 415{,}67 + 51{,}63*(\text{Environmental Awareness}) - 26{,}12*(\text{Environmental Responsibility}) + 12{,}78*(\text{Environmental Optimism})$$

The main factor positively influencing SL were "environmental awareness" and “environmental optimism”; the "environmental responsibility" was the negative affect.

4. Discussion, Implications and Recommendations

The results show that while the independent variables (effect of teacher, teaching, oneself and family) can be explained between approximately 8% of the total variance of the first model in environmental literacy, independent variables (environmental awareness, environmental responsibility, environmental optimism) can be explained between approximately 22% of the total variance of the second model in SL.

It is seen that the dimension that is related to the teacher has the most negatively effect on environmental literacy. Another similar study is stated that although the factor “teacher’s teaching skills” has positive and significant effect on environmental literacy, the factors “teacher's disposition to teach” and "Teacher's feedback for academic development of student" have a significant impact on environmental literacy in the negative direction in Estonia, Germany and Singapore (Kaya and Elster, 2018b). For this reason, teachers especially in the field of science should be encouraged to develop their competencies, especially their skills, dispositions to teaching, attitudes towards students during the pre-service and in-service training. Furthermore, they should also take over responsibility of their self-development to contribute to their professional development realistically (Kaya and Godek, 2016). On the other hand, the dimension of teaching has the positively effect on environmental literacy. Therefore, teacher training should provide opportunities for teacher candidates to develop their teaching skills.

It is seen that social perspectives (individuals themselves and their families) have a negatively effect on environmental literacy. Another study shows that 'attitude towards science' seems to have a positive effect on science literacy although ‘parents' educational level’ seems to have a negative effect on science literacy in Germany, Korea, and Turkey (Kaya, Godek, Elster and Polat, 2019). Moreover, ‘socio-economic characteristics’ and parents’ education have a significant effect on students’ academic achievement (Farooq’s et al., 2011). For this reason, both the students and their families should be supported for the quality of the education. For example, governments should pay more attention to public education. Experts should give seminars on how parents might support their children both personally and academically. On the other hand, it is also necessary to increase students' attitudes towards school and science. For instance, more extra-curricular activities such as computer programs and field trips should be included in formal training (Kaya and Elster, 2018b).

In addition, environmental awareness and optimism have a positive effect on the science achievement; but environmental responsibility has a negative effect on it. For this reason, while developing environment-related curriculums, it should be supported to gain more responsible behaviors towards the environment. Eventually, enhancing the environmental responsibility of the students might contribute to both environmental literacy and SL.

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2.1.2. Research Field-II: DELPHI STUDY

Kaya, V.H. and Elster, D. (Submitted). A Critical Consideration of Environmental Literacy: Concepts, Contexts and Competencies, *Sustainability*.

Kaya, V. H. and Elster, D. (2019). Environmental Science, Technology, Engineering, and Mathematics Pedagogical Content Knowledge: Teacher's Professional Development as Environmental Science, Technology, Engineering, and Mathematics Literate Individuals in the Light of Experts' Opinions, *Journal of Science Education International, 30*(1), 11-20.

There are 2 Delphi studies in the second research field. The aim of first Delphi study is to clarify the framework (concepts, contexts, and competencies) of the environmental literacy and to reach consensus on this framework in accordance with expert opinions. The purpose of the second Delphi study is to determine what teachers should do to develop their experiences and qualifications as environmental STEM literate individuals.

Prof. Dr. Doris ELSTER, who is my supervisor, supports me for preparing these publications. I clearly indicate that I contribute to these studies with my own academic skills and abilities. These studies were presented to the following international and national congress/conference.

Participations in Congress and Conference

Kaya, V.H. (2018). A Critical Consideration of Environmental Literacy: Concepts, Contexts and Competencies, Mixed Methods in Mathematics and Science Education Research (STEM) Season School, European Conference on Educational Research, March 12-13, 2018, University of Barcelona, Barcelona/SPAIN. (Oral Presentation).

Kaya, V.H. and Elster, D. (2018). Experts' Opinions: What should teachers do for develop their professional development as environmental STEM literate individuals? World STEM Education Conference, 7-10 June 2018, İstanbul/TURKEY (Oral Presentation).

2.1.2.1. A Critical Consideration of Environmental Literacy: Concepts, Contexts, and Competencies

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Abstract

This study is based on a Delphi study on environmental literacy which is an important part of science education. The main goal is to clarify the framework including concepts, contexts, and competencies of environmental literacy and to reach consensus on this framework in accordance with expert opinions. This study used a mixed method research design, which included both qualitative and quantitative methods, to reveal expert opinions. The exploratory sequential design, one type of mixed method research, was used in this Delphi study performed in three consecutive steps. The sample consisted of 45 experts who initially agreed to participate in this study with 20 of the 45 participating in the 1st step Delphi. The numbers of participants in the 2nd and 3rd Delphi steps are 44 and 31, respectively. This study concluded there was a consensus about the definition, sub-dimension, and competencies of environmental literacy and the institutions/social groups and people

responsible for the development of qualified environmentally literate individuals. Additionally, there was agreement concerning what to do to support the development of environmental literacy, topics that should be included in the curriculum and textbooks, and teaching methods and extra-curriculum activities for the development of environmental literacy.

Keywords: Environmental Literacy, Mixed-Methods, Delphi Study, Professional Development, Science Education

Introduction

In an ever-changing world, environmental concepts need to be updated to protect nature and natural life. In light of such updates, educational reforms are needed. The aim of this study was to update the concept of environmental literacy using a broad perspective of expert opinions from different countries.

Historical Development of Environmental Literacy

Environmental literacy in science and other disciplines is important because it enhances the protection of nature. However, environmental literacy is a concept that has evolved over time. In 1969, the concept of environmental literacy was first described (Roth, 1992). In 1972, environmental education gained international acknowledgement with the Stockholm Declaration (Belgrade Charter, 1975; Wright, 2002). In 1976, environmental education continued through organized meetings (The Belgrade Charter, 1976). The environmentally literate person is defined "who is environmentally competent in the affective domain, and in addition, is characterized by a values system in which one acts consistently in a manner compatible with the balance between quality of life and quality of environment (Harvey, 1976, p.252)". In 1977, UNESCO (1977) convened the first Intergovernmental Conference on Environmental Education in Tbilisi, resulting in the Tbilisi Declaration, which acknowledged the importance of environmental education in environmental conservation. In 1987, in the light of the UNESCO-UNEP International Congress on Environmental Education and Training, an international strategy for environmental education and training for youth and adults was developed (UNESCO-UNEP, 1987). In the same year, the World Commission on Environment and Development published Our Common Future about sustainable development (Rees, 1990). In the 1990s, environmental education became more rigorous for the development of environmentally literate individuals (McBeth and Volk, 2010). Moreover, environmental education programs were designed to raise and nurture the development of environmental literacy throughout one's lifetime (Subbarini, 1998). In 1992, more than 178 governments accepted the Agenda 21 program of action for sustainable development worldwide in Rio (UN, 1992). In 1993, the National Project for Excellence in Environmental Education was an effort, in part, to grapple with describing environmental literacy as well as the need to address the education reform agenda in the US (Simmons, 2007). In 1997, International Environmental Education Conference members suggested that environmental education be referred to as education for environment and sustainability in Thessaloniki (Knapp, 2010). In 2000, the Guidelines for Excellence in Environmental Education Project provided students, parents, educators, home schoolers, administrators, policy makers, and the public a set of common, voluntary guidelines for environmental education (2000-2010) (NAAEE, 2010). In 2002, European members of the World Summit on Sustainable Development in Johannesburg assessed the progress of Rio between 1992 to 2002 and discussed a new global agreement on sustainable development (von Schirnding, 2005). In 2005, UNESCO launched its Decade of Education for Sustainable Development

(2005-2014). In 2007, European and international representatives attended the conference “UN Decade of Education for Sustainable Development–the Contribution of Europe” in Berlin. During the same year, the 4th International Conference on Environmental Education in Ahmedabad reviewed the progress of the United Nations Decade of Education for Sustainable Development and reformulated Environmental Education (Centre for Environmental Education, 2007). In 2014, the “World Conference on Education for Sustainable Development: Learning Today for a Sustainable Future” in Aichi-Nagoya, Japan, marked the end of the UN Decade. It celebrated its achievements and launched the Global Action Program on Education for Sustainable Development (2015-2019).

Between 2017 and 2018, extensive research on environmental literacy was carried out with the support of the Ministry of National Education in Turkey and Bremen University in Germany. Kaya and Elster (2018b) suggest that large-scale assessments (such as PISA (Programme for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study), and PIRLS (Progress in International Reading Literacy Study)) involve and evaluate elements of environmental literacy. As a first step, the framework of environmental literacy is revised in this study, which is a part of the environmental literacy project.

Purpose of the Research

Human needs increase daily. This situation has positive and negative effects on the environment both directly and indirectly. However, it is necessary for individuals to be more sensitive to the environment to reduce the negative effects. This necessity also obliges the change in and development of the concept of environmental literacy. For this reason, studies continue to revise the components of environmental literacy and to promote environmental literacy (Disinger and Roth, 1992). The purpose of this research was to redefine and revise the concept of environmental literacy based on expert opinions. Thus, changes for the definition of this concept will be put forward and proposals to achieve increased environmental literacy will be presented. Expert opinions were taken from different professions (scientists, educators, and experts on environmental education) responsible for environmental education to conduct a comprehensive assessment of environmental literacy.

Importance of institutions/social groups/individuals

Individuals interact with the natural environment. Nevertheless, humans have more effect on the environment if their activities are based on collective entities, such as government and non-government organizations (Pfirman, and the AC-ERE, 2003). There is a need for environmentally literate individuals, which not only act individually, but also make well-informed public policy decisions collectively (NAAEE, 2010). In our world where individuals increasingly influence the natural systems that affect their quality of life, we need to educate individuals who can influence individual and societal decisions about environmental issues (Gunckel, et al., 2012). Therefore, we need more qualified environmentally literate people to protect and improve the environment and natural resources as a fundamental part of humans' well-being. It is necessary to carefully determine the responsible institutions and people to protect the natural environment. Moreover, these institutions and people may increase their awareness of the importance and the development of environmental literacy. In this way, it may be possible to increase the number of qualified environmentally literate individuals rapidly.

The importance of science curricula and textbooks for understanding systems related to the environment

To achieve a more sustainable future, current and potential future environmental problems as well as their possible solutions are included in science curricula and textbooks to raise awareness. The environmental problems are explained to allow learners to understand the importance of issues of the natural environment. For this reason, environmental field experts and environment education provide an opportunity for authors to determine what environmental issues should be addressed and how those issues should be explained in science curriculum and textbooks. The Sustainable Development Strategy study by the European Union is a good example. In 2006, the European Council determined seven key priority challenges for sustainable development (Federal Office for Spatial Development, 2018): climate change and clean energy; sustainable transport; sustainable consumption and production; conservation and management of natural resources; public health; social inclusion, demography, and migration; and global poverty and sustainable development challenges.

Sustainable development and its influences are key issues in the environmental field. Therefore, when preparing curricula or textbooks, the concept of environment should be presented with a broad perspective. Science curricula contain many interrelated systems related to the environment. For instance; human systems (such as political, economic, and cultural systems and their relationships) and interactions with physical and living systems are included in the scope of environmental literacy (Simmons, 2014). On the other hand, socio-ecological systems related to the environment include the understanding of many aspects of science, especially chemical and physical change, carbon cycling, water cycling, biodiversity, and evolution by natural selection (Anderson, 2007). In addition, socio-scientific issues, related to both social and environmental aspects, continue to be one of the basic concepts of science curricula. Current examples of socio-scientific issues are stem cell research, genetic engineering, cloning, and environmental problems (Sadler, et al., 2006). Nowadays, the relationship between engineering and environmental systems is increasing in importance, which is recognized in science education and curriculum development in the field of Science, Technology, Engineering and Mathematics (STEM) education. There is a need for further research about how individuals are influencing environmental systems (Tsurusaki and Anderson, 2010) and how to integrate engineering and environmental systems effectively. Simmons suggests the components of environmental literacy in the environmental education framework (Simmons, 1995:55-58, as cited in Hollweg, et al, 2011) are affect (e.g., environmental sensitivity, attitude, and moral reasoning); ecological knowledge; socio-political knowledge (e.g., the relationship of cultural, political, economic, and other social factors to ecology and environment); knowledge of environmental issues, skills regarding environmental problems/issues and action strategies, systemic thinking, and foresight; determinants of environmentally responsible behavior; and behavior (solving problems and resolving issues). Moreover, according to Hines, Hungerford and Tomera's (1987) results of the meta-analysis, it is concluded that the variables of 'knowledge of issues', 'knowledge of action strategies', 'the locus of control', 'attitudes', 'verbal commitment', and 'an individual's sense of responsibility' are associated with responsible environmental behavior.

Science curricula and textbooks that address environmental literacy may also provide opportunities to protect the natural environment and promote its effective use. Furthermore, science curricula and textbooks may be educational tools that help individuals learn concepts related to the natural environment and to put them into practice. Therefore, efficient science curricula and textbooks are some of the factors that contribute to the development of environmental literacy.

The impact of teaching methods and extra-curricular activities on achievement

The educational environment and activities provided to students are major factors affecting student achievement (Erden, 1988). For this reason, teachers should use different teaching methods in the classroom and in their lectures. Through these methods, the cognitive, emotional, and psychomotor skills of the students at diverse levels are developed more effectively to increase academic achievement and to promote the education of qualified environmentally literate individuals. Different teaching methods such as cooperative learning (Yapıcı, et al., 2009; Ebrahim, 2011; Parveen and Batool, 2012), varied discussion methods, inquiry-based learning (Abdi, 2014; Elster, et al., 2014; Maxwell, et al., 2015), and project-based learning (Ergül and Kargın, 2014; Cervantes, et al., 2015) have a positive impact on student achievement and learning. Moreover, individuals trained in new pedagogical education should have the skills, talents, and motivations to plan and manage change towards sustainability within a social environment (Smith, 2014).

On the other hand, improving the skills, talents, and motivations of students takes place inside as well as outside the schools. Extra-curricular activities (ECA) are any activities that occur outside of the school curriculum (Annu and Sunita, 2015). ECA provides opportunities for students to develop their motivations (such as moral and cognitive attitudes) and skills as well as to collaborate and communicate with their peers (Education Bureau, 2012; Simoncini, and Caltabiono, 2012). Students who participate in ECA have a chance to gain self-confidence and independence (Bakoban and Aljarallah, 2015). Moreover, ECA have a positive effect on environmental literacy (Kaya and Elster, 2018a). Therefore, these activities have become paramount elements of students' education and many schools allocate important resources to these activities (Seow and Pan, 2014). Non-mandatory ECA for students include activities such as discussions and workshops to achieve specific goals (Lucu and Platis, 2012). The experiences gained from ECA contribute to the social progress and individual development of the students (Foreman and Retallick, 2012). Even though all activities that take place in out-of-classroom settings are not beneficial for student success (Correa, et al., 2015), ECA have an overall positive effect on academic success at different academic levels (both school and university level) (Derous and Ryan, 2008; Wang and Shiveley, 2009; Manlove, 2013; Bakoban and Aljarallah, 2015).

Research Questions

The goal of this study was to clarify the framework (concepts, contexts, and competencies) of environmental literacy and to reach consensus on this framework based on expert opinions. Within the scope of this aim, answers to the following questions were sought:

Q1: How do experts define environmental literacy?

Q2: Which concepts and contexts are included in the framework of environmental literacy?

Q3: What are the competencies of the environmentally literate individual?

Q4: What should be done to promote the development of environmentally literate individuals?

Research Methods and Design

In this study, a mixed method research design was used to reveal expert opinions about the concept of environmental literacy. This type of research design combines qualitative and quantitative data *(Creswell, 2014, p. 14),* which provides a more comprehensive coverage of the research topic (Conti, 2012). The exploratory sequential design, a type of mixed method research, was used. Through the exploratory sequential design, the results of qualitative research are the basis for subsequent quantitative research, as can be seen in Figure 1 (Creswell, et al., 2011).

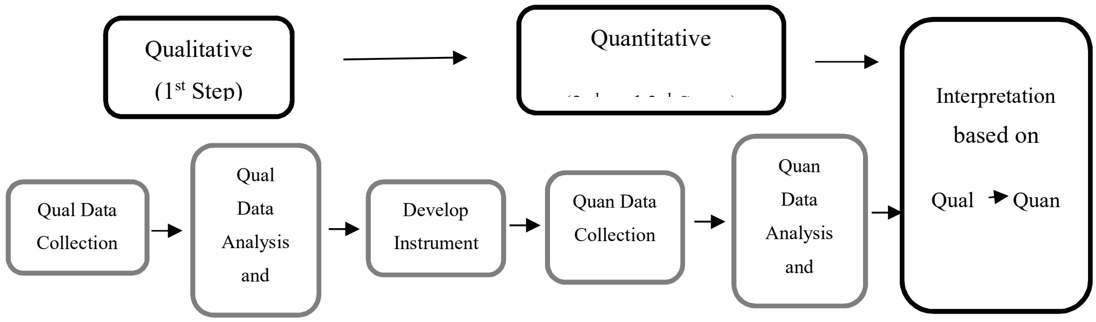

Figure 1: Exploratory Design: Instrument Development Model (Based on Creswell and Clark 2006, p. 73)

Based on expert opinions, the Delphi technique was utilized to determine the concept of environmental literacy and to develop the competencies of the environment literate individual. The Delphi technique is used for the collection of views on a specific topic (Villiers, Villiers, and Kent, 2005). It is a research technique used to obtain a common result using expert opinions to solve a complex problem (Aydin, 1999). This technique usually involves consecutive questionnaires directed to experts (Gencturk and Akbas, 2013) and allows them to explain their opinions freely without being influenced by the views of others (Ashmore, et al., 2016). In the Delphi technique, qualitative, quantitative, or mixed method research can be utilized (Skulmoski Hartman and Krahn, 2007). Therefore, the combined use of both the mixed method and the Delphi study techniques helps to uncover, define and reach consensus on the best practices and specific situations for the research topic (Conti, 2012).

In this study, as shown Figure 1, the Delphi study was performed in three consecutive steps. First, the qualitative data was collected. After the analyses of the data, the quantitative form was developed for the second step of the Delphi study. After the analyses of the data collected in the second step, the final quantitative form (for the third step) was prepared.

Sample

In a Delphi study, the selection of the sample is crucial (Vernon, 2009). The target sample population is experts in the area the researcher is assessing (Keeney, Hasson, and McKenna, 2001) to ensure the highest quality data (Bjil, 1992). The selection of experts in the field increases the reliability of Delphi studies. At this point, the characteristics of the universe are determined, and individuals with these characteristics can be selected for sampling (Johnson and Christensen, 2014). There must be at least seven experts in the sample, but the ideal group size is 10 to 20 experts. (Şahin, 2009). On the other hand, if the group is chosen homogeneously, a small sample (10 to 15 participants) may yield enough outcomes (Skulmoski, Hartman and Krahn, 2007). Therefore, experts with a Ph.D. specializing in EE were included for the creation of a homogeneous sample. These experts within the homogeneously selected sample worked at different universities in different countries and to ensure maximum variation in the sample. Initially, 45 experts who work as a scientist/an educator/a teacher in countries of the European Union and candidates' countries of the European Union (40), the United States and Africa (5) agreed to participate. However, the numbers of the participants in the 1st, 2nd, and 3rd Delphi study steps were 20, 44, and 31, respectively.

Process of the Delphi Study

The Delphi technique prevents participants' direct discussion with each other, and through interviews or questionnaires, participants can question the situation repeatedly (Dalkey and Halmer, 1963). It is used as a means of providing consensus among experts in situations where there are differences of opinion (Şahin, 2001). In this study, the Delphi study was carried out in three steps as seen in Figure 2. Each round contained the data collection tool, the collection of data, and the analysis of these collected data.

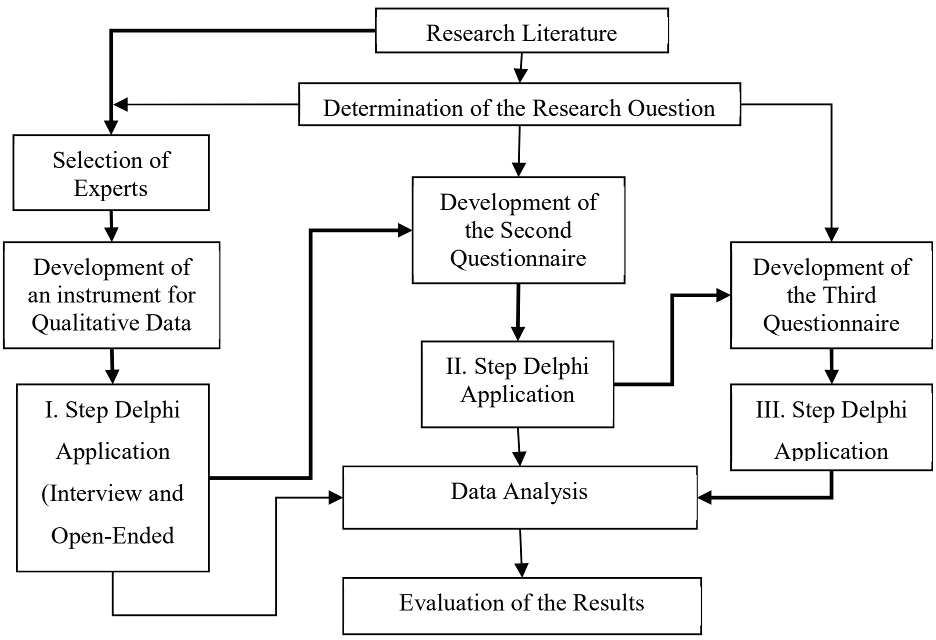

Figure 2: Process of the Delphi Study

The development of questionnaire forms and data analysis methods are structured according to the three steps (Schulte, 2017). However, in the Delphi method, qualitative data from the first round is obtained, and then this data provides the basis for the quantitative data in both the second and third rounds (Cartwright, 2014).

First Round

For the first round of the Delphi study, a questionnaire including structured open-ended questions and demographics was used to receive participants' opinions both using paper and pencil forms and interviews. In light of the literature, 13 questions were asked in the draft questionnaire. After the feedback and review of two scientists, the final version of the questionnaire contained nine questions that were hierarchically ranked (Appendix 1). The structured open-ended questionnaires were sent to all participants and interviews were also conducted with three randomly selected experts. In the 1st step Delphi, 20 of the 45 experts participated. The data obtained in the first round were analyzed using the content analysis method, which allows researchers to identify collected data and reveal hidden information in the data (Gülbahar and Alper, 2009). Content analysis helps to identify the concepts and categories that explain the collected data (Tüzel, 2013; Güzel and Meder, 2010).

Second Round

The responses from the first round were converted into Likert-scale items. In the survey, a 7-item Likert-scale was used between “Strongly agree” (7) and “Strongly disagree” (1). Moreover, the experts could share their opinions for each item in the questionnaire. By this means, participation levels for each item were determined. For the validity and reliability of the prepared questionnaire, opinions were taken from two scientists related to EE and one linguist. A pilot study involving 40 people was conducted. However, 4 persons only answered a few questions in the survey. Therefore, this data was not included in the analysis. Linear trend at point, which is a method of completing missing data, was used for each question answered by 36 people. The obtained reliability results are given in Table 1.

Table 1: Reliability analysis summary

Reliability Statistics		
Construction	**Cronbach's Alpha**	**N of items**
Question 1: Definition of environmental literacy	0.70	5
Question 2: Sub-dimensions of environmental literacy	0.78	7
Question 3: Competencies of environmental literacy	0.92	10
Question 4: Institutions/social groups responsible for the development of qualified environmentally literate individuals	0.90	10
Question 5: People responsible for the development of qualified environmentally literate individuals	0.91	13
Question 6: What to do to support the development of qualified environmental literacy	0.92	11
Question 7: Topics that should be included in the curriculum and textbooks for the development of environmental literacy	0.85	7
Question 8: Teaching methods for the development of environmental literacy	0.82	11
Question 9: Extra-curriculum activities for the development of environmental literacy	0.86	7
Total	0.97	81

Each construction contained 5 to 13 questions. The Cronbach's alpha coefficients of these constructions ranged from 0.92 to 0.70. Moreover, the Spearman-Brown split-half reliability coefficient was used (0.92).

Third Round

The items in the third questionnaire were the same as in the second round questionnaire. By considering the results of the second round, a question was added to the definition and sub-dimensions of environmental literacy, and other experts' opinions were sought in this regard. The difference between the third and second questionnaires was that the statistical data (arithmetic mean, standard deviation, and quartile difference) obtained from the second questionnaire were shared with participants on the third questionnaire. In this respect, the participants had the opportunity to evaluate each item while considering the statistical data from the second round.

Methods of Data Analysis

To understand whether consensus was reached statistically, the mean ($\bar{x}$), standard deviation (sd), median (med), difference between quarters (DBQ), percent of responses, consensus (cons), and consensus difference between the second and third round analyses (cons. dif.) are given in the tables. Table 2 describes how consensus was determined. If the median was greater than or equal to 5, the DBQ was less than or equal to 1.5, and the frequencies of "agree" (Likert-scale of 5-7) were greater than or equal to 70%, consensus was reached.

Table 2: Indicator of Consensus (Şahin, 2009)

Consensus	Indicator of Consensus
Consensus Criteria	If median $\geq$ 5 and DBQ $\leq$ 1.5 and 5-7 frequencies $\geq$ 70%
Consensus Not Reached	If median $\leq$ 3 and DBQ $\leq$ 2.5 and 1-3 frequencies $\geq$ 70%

Results

The results obtained at the end of the first round were used in both the 2nd and 3rd rounds. Each question represents each theme and each item represents each code. Therefore, the results obtained from the 1st round are not included in this section.

Table 3: Components of the definition of environmental literacy

Item	Round	$\bar{x}$	Sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Knowledge and understanding of environmental issues	**2.R.**	6.18	1.24	6.50	1.00	95.5	-	4.5	**Yes**	1.3
	3.R.	6.58	0.72	7.00	1.00	96.8	3.2	-	**Yes**	
Attitudes and concern towards the environment	**2.R.**	6.30	1.13	7.00	1.00	93.2	-	6.8	**Yes**	3.6
	3.R.	6.45	1.18	7.00	1.00	96.8	-	3.2	**Yes**	
Morals and ethics towards the environment	**2.R.**	6.33	1.23	7.00	1.00	83.7	9.3	7.0	**Yes**	3.1
	3.R.	6.55	0.85	7.00	1.00	96.8	-	3.2	**Yes**	
Intention to act with environmentally responsible behavior	**2.R.**	6.26	1.12	7.00	1.00	95.3	-	4.7	**Yes**	1.4
	3.R.	6.53	0.82	7.00	1.00	96.7	-	3.3	**Yes**	
* *Improved skills to evaluate data, draw conclusions, and form opinions*	**2.R.**	-	-	-	-	-	-	-	**-**	-
	3.R.	6.11	1.20	6.00	1.00	84.2	10.5	5.3	**Yes**	
Interrelationship of knowledge, understanding, attitude, morals and ethics, and intentions and behaviors towards the environment	**2.R.**	5.80	1.61	6.00	2.00	81.8	9.1	9.1	**No**	-1.2
	3.R.	6.03	1.49	7.00	2.00	80.6	9.7	9.7	**No**	

* According to step 2 analysis results, one item was added in the step 3 questionnaire based on the experts' suggestions.

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 3, at the end of Delphi study, consensus was reached for all items except interrelationship of knowledge, understanding, attitude, morals and ethics, and intention and behavior towards the environment. In addition, there was consensus on the concept added to the definition of environmental literacy based on expert opinions at the end of the second round (improved skills to evaluate data, draw conclusions, and form opinions), which is related to the cognitive dimension.

Table 4: Sub-dimensions of environmental literacy

Item	**Round**	**$\bar{x}$**	**sd**	**Med**	**DBQ**	**Responses %**			**Cons**	**Cons. Dif.**
						5-7	**4**	**1-3**		
Knowledge and understanding about environmental issues	**2.R.**	6.23	0.74	6.00	1.00	97.6	2.4	-	**Yes**	-10.6
	3.R.	6.16	1.21	7.00	1.00	87	6.5	6.5	**Yes**	
"*legislation about environment*" should be added to the above item *	**2.R.**	-	-	-	-	-	-	-	-	-
	3.R.	5.40	1.77	6.00	3.00	73.4	13.3	13.3	**No**	
Environmental attitudes	**2.R.**	6.37	0.87	7.00	1.00	95.3	4.7	-	**Yes**	1.5
	3.R.	6.48	0.77	7.00	1.00	96.8	3.2	-	**Yes**	
Environmental motivation	**2.R.**	6.23	1.00	6.00	1.00	90.7	7.0	2.3	**Yes**	6.1
	3.R.	6.48	0.85	7.00	1.00	96.8	-	3.2	**Yes**	
Morals and ethics related to the environment	**2.R.**	6.37	0.85	7.00	1.00	95.3	4.7	-	**Yes**	4.7
	3.R.	6.55	0.62	7.00	1.00	100	-	-	**Yes**	
Intention to act in an environmentally-friendly manner	**2.R.**	6.42	0.76	7.00	1.00	97.7	2.3	-	**Yes**	-0.9
	3.R.	6.55	0.81	7.00	1.00	96.8	3.2	-	**Yes**	
Environmentally-friendly behaviors	**2.R.**	6.55	0.63	7.00	1.00	100	-	-	**Yes**	0
	3.R.	6.74	0.45	7.00	1.00	100	-	-	**Yes**	
Sustainability	**2.R.**	6.48	0.85	7.00	1.00	95.5	4.5	-	**Yes**	4.5
	3.R.	6.77	0.56	7.00	0.00	100	-	-	**Yes**	

* According to step 2 analysis results, this item was added in the step 3 questionnaire based on the experts' suggestion.

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 4, at the end of Delphi study, consensus was reached on all sub-dimensions of environmental literacy. However, no consensus was reached on the item legislation about the environment, which was added to the third round. When 2nd and the 3rd Delphi results are compared, the percentage of environmental attitudes and motivation, morals and ethics related to the environment, sustainability are increased.

Table 5: Competencies of environmental literacy

Item	Round	$\bar{x}$	Sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Knowledge and understanding about environment issues	2.R.	6.50	0.75	7.00	1.00	97.5	2.5	-	Yes	-0.7
	3.R.	6.68	0.70	7.00	0.00	96.8	3.2	-	Yes	
Responsibility towards the environment	2.R.	6.54	0.78	7.00	1.00	97.6	2.4	-	Yes	2.4
	3.R.	6.65	0.71	7.00	0.00	100	-	-	Yes	
Awareness towards environmental issues	2.R.	6.56	0.67	7.00	1.00	100	-	-	Yes	0
	3.R.	6.61	0.62	7.00	1.00	100	-	-	Yes	
Motivation towards the environment	2.R.	6.42	0.77	7.00	1.00	97.6	2.4	-	Yes	-0.6
	3.R.	6.49	0.81	7.00	1.00	96.8	3.2	-	Yes	
Morals and ethics towards environmental issues	2.R.	6.46	0.81	7.00	1.00	97.6	2.4	-	Yes	-0.6
	3.R.	6.58	0.89	7.00	1.00	96.8	-	3.2	Yes	
Social engagement related to the environment	2.R.	6.12	1.05	6.00	1.00	95.2	2.4	2.4	Yes	1.6
	3.R.	6.36	1.08	7.00	1.00	96.8	-	3.2	Yes	
Intention to act to protect the environment	2.R.	6.49	0.81	7.00	1.00	97.6	-	2.4	Yes	-0.6
	3.R.	6.65	0.88	7.00	0.00	96.8	-	3.2	Yes	
Positive behavior towards the environment	2.R.	6.66	0.66	7.00	1.00	97.6	2.4	-	Yes	2.4
	3.R.	6.87	0.43	7.00	0.00	100	-	-	Yes	
Sustainable knowledge about the environment	2.R.	6.44	0.81	7.00	1.00	95.1	4.9	-	Yes	1.7
	3.R.	6.74	0.68	7.00	0.00	96.8	3.2	-	Yes	
Concrete sustainable activities towards the environment	2.R.	6.07	1.03	6.00	2.00	90.2	9.8	-	No	3.3
	3.R.	6.42	0.92	7.00	1.00	93.5	6.5	-	Yes	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 5, at the end of Delphi study (3rd Step), consensus was reached on all items regarding what is necessary to achieve environmental literacy. However, there was no agreement about concrete sustainable activities towards the environment in the step 2 Delphi.

When 2nd and the 3rd Delphi results are compared, the percentage of responsibility towards the environment, social engagement related to the environment, ositive behavior towards the environment, sustainable knowledge about the environment and concrete sustainable activities towards the environment are increased.

Table 6: Institutions/social groups responsible for the development of qualified environmentally literate individuals

Item	Round	$\bar{x}$	Sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	**4**	**1-3**		
Social environment (family, friends, etc.)	**2.R.**	6.29	1.03	7.00	1.00	97.6	-	2.4	**Yes**	-0.6
	3.R.	6.42	1.09	7.00	1.00	96.8	-	3.2	**Yes**	
School (formal education)	**2.R.**	6.46	0.98	7.00	1.00	97.6	-	2.4	**Yes**	-0.6
	3.R.	6.58	0.99	7.00	1.00	96.8	-	3.2	**Yes**	
University	**2.R.**	6.39	0.80	7.00	1.00	100	-	-	**Yes**	-3.2
	3.R.	6.32	0.87	7.00	1.00	96.8	3.2	-	**Yes**	
State	**2.R.**	5.88	1.49	6.00	2.00	87.8	2.4	9.8	**No**	2.5
	3.R.	6.19	1.35	7.00	1.00	90.3	6.5	3.2	**Yes**	
Ministry of education	**2.R.**	6.27	1.23	7.00	1.00	85.4	12.2	2.4	**Yes**	4.9
	3.R.	6.48	1.15	7.00	1.00	90.3	6.5	3.2	**Yes**	
Public departments	**2.R.**	5.98	1.28	6.00	2.00	85.3	9.8	4.9	**No**	-4.7
	3.R.	6.00	1.48	7.00	1.00	80.6	12.9	6.5	**Yes**	
Municipalities	**2.R.**	6.34	1.11	7.00	1.00	90.2	4.9	4.9	**Yes**	-3.1
	3.R.	6.32	1.30	7.00	1.00	87.1	6.5	6.4	**Yes**	
Industries	**2.R.**	5.83	1.86	7.00	2.00	83.0	2.4	14.6	**No**	0.9
	3.R.	5.90	1.87	7.00	1.00	83.9	-	16.1	**Yes**	
Citizen associations	**2.R.**	6.10	1.43	7.00	1.00	82.5	12.5	5.0	**Yes**	-7.8
	3.R.	6.13	1.18	6.00	1.00	90.3	6.5	3.2	**Yes**	
Public media	**2.R.**	6.39	1.05	7.00	1.00	90.3	7.3	2.4	**Yes**	6.4
	3.R.	6.57	0.77	7.00	1.00	96.7	3.3	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 6, at the end of Delphi study, there was a consensus on all items regarding the institutions that are responsible for the development of environmentally literate individuals. When 2nd and the 3rd Delphi results are compared, the percentage of state, ministry of education, industries, citizen associations and public media are increased.

Table 7: People responsible for the development of qualified environmentally literate individuals

Item	Round	$\bar{x}$	sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Family (mother, father, etc.)	**2.R.**	6.49	0.87	7.00	1.00	97.6	-	2.4	**Yes**	-0.6
	3.R.	6.45	0.96	7.00	1.00	96.8	-	3.2	**Yes**	
Friends	**2.R.**	5.82	1.21	6.00	2.00	92.3	2.6	5.1	**No**	-12.3
	3.R.	5.67	1.56	6.00	2.00	80.0	13.3	6.7	**No**	
Individual (himself/herself)	**2.R.**	6.43	1.20	7.00	1.00	95.0	-	5.0	**Yes**	-1.7
	3.R.	6.40	1.33	7.00	1.00	93.3	-	6.7	**Yes**	
Educators	**2.R.**	6.63	0.66	7.00	1.00	97.6	2.4	-	**Yes**	-3.1
	3.R.	6.61	0.80	7.00	1.00	93.5	6.5	-	**Yes**	
Academics	**2.R.**	6.27	1.00	7.00	1.00	90.2	9.8	-	**Yes**	3.1
	3.R.	6.26	1.03	7.00	1.00	87.1	12.9	-	**Yes**	
Scientists	**2.R.**	6.25	1.24	7.00	1.00	87.5	10.0	2.5	**Yes**	0.2
	3.R.	6.23	1.28	7.00	1.00	87.7	10.0	3.3	**Yes**	
Teachers	**2.R.**	6.71	0.68	7.00	0.00	97.6	2.4	-	**Yes**	-0.6
	3.R.	6.65	0.71	7.00	1.00	96.8	3.2	-	**Yes**	
Employees who work at School	**2.R.**	5.80	1.42	6.00	2.00	82.5	10.0	7.5	**No**	0.9
	3.R.	5.77	1.23	6.00	2.00	83.4	13.3	3.3	**No**	
Country administrators	**2.R.**	5.88	1.68	7.00	2.00	85.4	-	14.6	**No**	1.7
	3.R.	6.07	1.50	7.00	2.00	87.1	3.2	9.7	**No**	
Policy makers	**2.R.**	5.80	1.79	7.00	1.75	82.5	2.5	15.0	**No**	0.8
	3.R.	6.10	1.63	7.00	1.00	83.3	6.7	10.0	**Yes**	
Entrepreneurs	**2.R.**	5.56	1.92	6.00	2.00	78.0	4.9	17.1	**No**	2.0
	3.R.	5.73	1.83	7.00	2.00	80.0	3.3	16.7	**No**	
Business people	**2.R.**	5.58	1.80	6.00	2.00	80.0	7.5	12.5	**No**	3.3
	3.R.	5.60	1.27	6.50	2.00	83.3	3.3	13.3	**No**	
Artists	**2.R.**	6.13	1.44	7.00	1.75	82.5	12.5	5.0	**No**	4.2
	3.R.	6.03	1.87	7.00	2.00	86.7	10.0	3.3	**No**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 7, at the end of Delphi study, there was a consensus on seven items (family, individual (himself/herself), educators, academics, scientists, teachers, and policy makers) who have responsibility for the development of qualified environmentally literate individuals. However, there was no consensus on the remaining six items (friends, employees who work at schools, country administrators, entrepreneurs, business people, and artists). The institutions/social groups and people that have a responsibility for the development of qualified environmentally literate individuals are varied. Experts believe that states and public media are responsible for the development of environmentally literate individuals; however, country administrators who manage the states and artists are not responsible. In addition, people (business people and entrepreneurs) who work in industry are not responsible for the development of environmentally literate individuals, however, industries are responsible.

The experts suggest that governments, families, teachers, non-governments organizations and public media should support the development of qualified environmental literacy. The families and teachers should inform children about environmental issues, promote the acquisition of morals and ethics towards the environment, and guide the development of positive attitudes towards the environment. Moreover, teachers should support student development of intentions to act and show environmentally-friendly behavior. Governments should mandate the inclusion of more environmental topics and their practice in science curricula and support the environmental qualifications of their teachers. Non-government organizations should support participation in social, civil, and/or societal initiatives. Public media (newspapers, TV, etc.) should support learning about environmental issues.

Table 8a: What to do to support the development of environmental literacy

Item	Round	$\bar{x}$	sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
The family should inform their children about environmental issues	**2.R.**	6.49	0.93	7.00	1.00	95.2	2.4	2.4	**Yes**	1.6
	3.R.	6.68	0.79	7.00	0.00	96.8	3.2	-	**Yes**	
The family should support their children to gain morals and ethics towards the environment	**2.R.**	6.56	0.78	7.00	1.00	97.6	2.4	-	**Yes**	-0.8
	3.R.	6.61	0.80	7.00	0.00	96.8	3.2	-	**Yes**	
The family should support their children to gain positive attitudes towards the environment	**2.R.**	6.49	0.90	7.00	1.00	95.1	4.9	-	**Yes**	4.9
	3.R.	6.71	0.69	7.00	0.00	100	-	-	**Yes**	
Teachers should inform their students about environmental issues	**2.R.**	6.71	0.56	7.00	0.50	100	-	-	**Yes**	0
	3.R.	6.81	0.48	7.00	0.00	100	-	-	**Yes**	
Teachers should support their students to gain morals and ethics towards the environment	**2.R.**	6.66	0.69	7.00	0.00	100	-	-	**Yes**	0
	3.R.	6.68	0.60	7.00	1.00	100	-	-	**Yes**	
Teachers should support their students to gain positive attitudes towards the environment	**2.R.**	6.66	0.73	7.00	0.00	97.6	2.4	-	**Yes**	2.4
	3.R.	6.74	0.51	7.00	0.00	100	-	-	**Yes**	
Teachers should support their students to gain intentions to act with and show environmentally-friendly behavior	**2.R.**	6.76	0.62	7.00	0.00	97.6	2.4	-	**Yes**	-2.4
	3.R.	6.71	0.59	7.00	0.00	100	-	-	**Yes**	
In science curricula, more environmental topics and their practices should be included	**2.R.**	6.39	0.97	7.00	1.00	92.7	4.9	2.4	**Yes**	4.1
	3.R.	6.52	0.81	7.00	1.00	96.8	3.2	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

Table 8b: What to do to support the development of environmental literacy

Item	Round	$\bar{x}$	sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Governments should support the qualifications of their teachers.	**2.R.**	6.44	1.21	7.00	1.00	94.9	-	5.1	**Yes**	-1.6
	3.R.	6.40	1.30	7.00	1.00	93.3	-	6.7	**Yes**	
Non-government organizations should support individuals to take part in social, civil, and/or societal initiatives	**2.R.**	6.32	1.06	7.00	1.00	92.7	2.4	4.9	**Yes**	4.1
	3.R.	6.48	0.89	7.00	1.00	96.8	3.2	-	**Yes**	
Public Media (such as newspaper, TV, etc.) should support individuals to learn about environmental issues.	**2.R.**	6.37	1.07	7.00	1.00	92.7	4.9	2.4	**Yes**	7.3
	3.R.	6.68	0.65	7.00	0.00	100	-	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 8, at the end of Delphi study, there was a consensus on 11 items about what should be done to enhance the development of environmentally literate individuals. When 2nd and the 3rd Delphi results are compared, the percentage of 'the family should inform their children about environmental issues', 'the family and teachers support their children to gain positive attitudes towards the environment', 'teachers should support their students to gain intentions to act with and show environmentally-friendly behavior', 'in science curricula, more environmental topics and their practices should be included' and 'non-government organizations and public media should support individuals to take part in social and to learn about environmental issues' are increased.

Table 9.: Topics that should be included in the curriculum and textbooks for the development of environmental literacy

Item	Round	$\bar{x}$	sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Environmental perceptions (attitude, responsibilities, morals, etc.)	**2.R.**	6.46	0.93	7.00	0.00	91.9	8.1	-	**Yes**	1.6
	3.R.	6.55	0.85	7.00	1.00	93.5	6.5	-	**Yes**	
Examples of environmentally-friendly behavior	**2.R.**	6.69	0.62	7.00	0.00	97.2	2.8	-	**Yes**	2.8
	3.R.	6.65	0.55	7.00	1.00	100	-	-	**Yes**	
Nature of environmental concepts (ecosystems, ecology, natural resources, etc.)	**2.R.**	6.62	0.64	7.00	0.00	100	-	-	**Yes**	0.0
	3.R.	6.77	0.43	7.00	0.00	100	-	-	**Yes**	
Examples of environmental problems (global warming, climate change, endangered species, etc.)	**2.R.**	6.76	0.55	7.00	0.00	100	-	-	**Yes**	0.0
	3.R.	6.90	0.40	7.00	0.00	100	-	-	**Yes**	
Solutions for environmental problems (recycling, renewable energy, etc.)	**2.R.**	6.60	0.73	7.00	1.00	97.3	2.7	-	**Yes**	-3.8
	3.R.	6.61	0.84	7.00	0.00	93.5	6.5	-	**Yes**	
Sustainability (sustainable development and future, etc.)	**2.R.**	6.60	0.69	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.77	0.50	7.00	0.00	100	-	-	**Yes**	
Social perspectives (interrelationship of environment, society, and technology, etc.)	**2.R.**	6.38	1.04	7.00	1.00	91.9	5.4	2.7	**Yes**	4.9
	3.R.	6.61	0.76	7.00	1.00	96.8	3.2	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 9, at the end of Delphi study, there was consensus on seven items regarding topics that should be included in the curricula and textbooks for the development of environmental literacy. When 2nd and the 3rd Delphi results are compared, the percentage of environmental perceptions, examples of environmentally-friendly behavior and social perspectives are increased.

Table 10: Teaching methods for the development of environmental literacy

Item	Round	$\bar{x}$	Sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Experiments	**2.R.**	6.23	1.09	7.00	1.00	94.3	2.9	2.9	**Yes**	-1.2
	3.R.	6.28	0.84	6.00	1.00	93.1	6.9	-	**Yes**	
Knowledge transmission (direct instruction, expository instruction)	**2.R.**	5.14	1.68	5.00	0.25	77.8	2.8	19.4	**Yes**	-24.5
	3.R.	4.23	2.13	5.00	3.25	53.3	10.0	36.7	**No**	
Project-based learning	**2.R.**	6.61	0.65	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.65	0.55	7.00	1.00	100	-	-	**Yes**	
Documentaries and videos	**2.R.**	6.00	0.88	6.00	2.00	94.6	5.4	-	**No**	-1.0
	3.R.	5.87	1.20	6.00	2.00	93.6	3.2	3.2	**No**	
Context-based learning	**2.R.**	6.08	1.06	6.00	2.00	91.9	5.4	2.7	**No**	1.6
	3.R.	6.16	0.90	6.00	1.00	93.5	6.5	-	**Yes**	
Problem-based learning	**2.R.**	6.54	0.77	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.65	0.66	7.00	1.00	100	-	-	**Yes**	
Different discussion methods	**2.R.**	6.41	0.69	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.58	0.62	7.00	1.00	100	-	-	**Yes**	
Inquiry-based learning	**2.R.**	6.57	0.80	7.00	1.00	97.3	2.7	-	**Yes**	-0.5
	3.R.	6.61	0.76	7.00	1.00	96.8	3.2	-	**Yes**	
Out-of-school activities	**2.R.**	6.62	0.76	7.00	0.00	100	-	-	**Yes**	0.0
	3.R.	6.68	0.70	7.00	0.00	100	-	-	**Yes**	
Hands-on experience	**2.R.**	6.65	0.89	7.00	0.00	91.9	8.1	-	**Yes**	1.6
	3.R.	6.65	0.84	7.00	0.00	93.5	6.5		**Yes**	
Collaborative learning	**2.R.**	6.60	0.64	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.65	0.61	7.00	1.00	100	-	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 10, at the end of Delphi study, there was a consensus on all items except for knowledge transmission (direct instruction, expository instruction) and documentaries and videos. At the end of the 2nd round, there was a consensus on knowledge transmission, which disappeared at the end of the 3rd round. Teachers should use varied teaching methods in science classes for development of environmental literacy such as out-of-school activities, collaborative learning, inquiry-based learning, project-based learning, experiments, context-based learning, problem-based learning, varied discussion methods, and hands-on experiences.

Table 11: Views regarding extra-curriculum activities for the development of environmental literacy

Item	Round	$\bar{x}$	Sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	**4**	**1-3**		
Watch TV programs about the environment	**2.R.**	6.19	0.94	7.00	2.00	97.3	2.7	-	**No**	-7.0
	3.R.	5.97	1.33	6.00	2.00	90.3	6.5	3.2	**No**	
Visit web sites of environment organizations	**2.R.**	5.73	1.19	6.00	1.50	94.6	-	5.4	**Yes**	-7.6
	3.R.	5.51	1.21	6.00	1.00	87.0	6.5	6.5	**Yes**	
Participate in environment clubs and activities	**2.R.**	6.24	0.86	6.00	1.00	94.6	5.4	-	**Yes**	2.2
	3.R.	6.58	0.77	7.00	1.00	96.8	3.2	-	**Yes**	
Visit botanical garden	**2.R.**	6.27	0.96	7.00	1.50	96.6	4.4	-	**Yes**	-3.3
	3.R.	6.10	0.96	6.00	2.00	93.3	6.7	-	**No**	
Read a book/newspaper about the environment	**2.R.**	6.11	1.02	6.00	2.00	91.9	8.1	-	**No**	-4.8
	3.R.	6.03	1.14	7.00	2.00	87.1	12.9	-	**No**	
Visit museums of science and the arts	**2.R.**	6.06	1.22	7.00	2.00	88.8	5.6	5.6	**No**	4.7
	3.R.	6.13	0.92	6.00	1.00	93.5	6.5	-	**Yes**	
Field trips and excursions	**2.R.**	6.33	1.24	7.00	1.00	94.4	-	5.6	**Yes**	5.6
	3.R.	6.67	0.61	7.00	1.00	100	-	-	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 11, although there was no consensus on the items of watch TV programs about the environment, read a book/newspaper about the environment, and visit museums of science and the arts in the 2nd round, there was consensus on visit museums of science and the arts in the 3rd round. There was consensus on visiting botanical gardens in the 2nd round, but there was no consensus at the end of the 3rd round.

These research findings emphasize that teachers should be supported both for individual and professional development to educate qualified environmentally literate individuals. In addition, teachers should be aware of the importance of teaching methods (project-based learning, problem-based learning, etc.) and ECA (participate in environmental club and activities, field trips and excursions, etc.) for the development of environmental literacy.

Discussion and Conclusion

According to the results of the 2nd step Delphi, there was not consensus on 17 of 81 items. Therefore, the 3rd step of the Delphi study was necessary. The 3rd step Delphi study improved to a lack of consensus on 12 of 81 items. In the light of expert opinions, the concepts that need to be included in the definition of environmental literacy are “knowledge and understanding of environmental issues”, “attitudes and concern towards the environment”, “morals and ethics towards the environment”, and “intent to act with environmentally responsible behavior” as well as, “promotion of skills to evaluate data, draw conclusions, and form opinions”.

The current definition of environmental literacy includes common concepts such as the ability to perceive, interpret, and make informed decision about environmental issues, understand ecosystems, and be aware of the importance of natural phenomena (Roth, 1992; Minner and Klein, 2016; North Carolina. Department of Environmental Quality, 2017). This study expands on this definition and shows that it is necessary to include concepts of morals and ethics towards the environment; knowledge, understanding, attitude, morals and ethics, and intention and behavior towards the environment; and development of skills to evaluate data, draw conclusions, and form personal opinions in the definition of environmental literacy. Additionally, the sub-dimensions of environmental literacy are knowledge and understanding about environmental issues, environmental attitudes, environmental motivation, morals and ethics related to the environment, intention to act in an environmentally-friendly manner, environmentally-friendly behaviors, and sustainability.

Common sub-dimensions related to environmental literacy are knowledge, attitudes, values, skills, responsibility, and active involvement (UNESCO, 1977; Roth, 1992; Kaya and Elster, 2017). However, future environmental literacy research should include morals and ethics, motivation, and sustainability. Besides attitude and behavioral control personal moral norm is a variable of pro-environmental behavioral intention (Bamberg and Mesör, 2007). In the light of expert opinions, environmental literacy competencies that come to the forefront are knowledge and understanding about environment issues, responsibility towards the environment, awareness of environmental issues, motivation towards the environment, morals and ethics regarding environmental issues, social engagement related to the environment, intention to act to protect the environment, positive behavior towards the environment, sustainable knowledge about the environment, and concrete sustainable activities towards the environment.

Teaching skills and a teacher's disposition are important for the development of qualified environmentally literate individuals (Kaya and Elster, 2018a). Therefore, it is necessary to focus on teacher training and professional development, especially on the use of effective teaching methods for teaching and integrating environmental issues into the curricula

(National Environmental Education Advisory Council, 2015). The following topics should be included in the curriculum and textbooks for the development of environmental literacy:

- Environmental perceptions (attitude, responsibility, morals, etc.),
- Examples of environmentally-friendly behavior (such as saving and protecting natural resources, etc.),
- Nature of environmental concepts (ecosystem, ecology, and natural resources, etc.),
- Examples of environmental problems (global warming, climate change, and endangered species, etc.),
- Solutions for environmental problems (recycling and renewable energy, etc.),
- Sustainability (sustainable development and future, etc.),
- Social perspectives (interrelationship of environment, society, and technology, etc...).

In general, concrete examples and predicted future environmental problems should be emphasized more than the theoretical concepts related to biology in the curricula and textbooks. However, in general, environmental knowledge are highly emphasized in the school curriculum (Karimzadegan and Meiboudi, 2012). In addition, for the development of environmental literacy, it is crucial to be aware of the importance of ECA such as visiting web sites of environmental organizations, participating in environmental clubs, visiting science and art museums, and taking field trips. ECA not only have a positive effect on achievement at different academic levels (Derous and Ryan, 2008; Wang and Shiveley, 2009; Manlove, 2013; Bakoban and Aljarallah, 2015), but also promote student passions, skills, cooperation, and communication with their peers (Education Bureau, 2012; Simoncini, and Caltabiono, 2012). The educational interventions can effectively enhance environmental behavior (Zelezny, 1999). Moreover, ECA have a positive effect on environmental literacy (Kaya and Elster, 2018a). The study shows that the active involvement and social engagement related to the environment and the importance of ECAs in promoting cooperation and communication with peers and suggestions are shared about ECA examples for the development of environmental literacy based on expert opinions.

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

Recommendations

Based on the research results, the scope and definition of environmental literacy were revised in line with the opinions of experts. Moreover, the competencies of environmental literacy were enumerated. Therefore, our results should not only guide curriculum developers, researchers, and stakeholders, but also suggest what teachers should do to educate qualified environmentally literate individuals.

The new definition of environmental literacy based on our results is *'knowing and understanding environmental issues; having attitudes, concerns, morals, and ethics towards the environment; having the ability and intention to act with environmentally responsible behavior; having the active involvement and social engagement related to the environment as well as having skills to evaluate data and draw conclusions to form one's own opinion and collaboratively working with stakeholders to solve environmental issues.'*

Researchers and curriculum developers should consider this definition of environmental literacy as well as the seven sub-dimensions and ten competencies when evaluating environmental literacy. Teachers have a significant role in educating environmentally literate individuals. In the teaching process, teachers should use the project-based learning approach, varied discussion methods, out-of-school activities, and collaborative learning instead of direct instruction and expository instructional teaching. Moreover, our results show teachers' professional development is a key factor that affects the development of environmentally literate individuals. Thus, qualified environmentally literate individuals requires qualified environmentally literate teachers.

Additional EE should become part of the academic teacher training programs in universities. In particular, the concept of "environment" should be integrated into the framework of PCK for teacher’s professional development. Teachers, as well as families and governments, have an important responsibility for directing and encouraging students to attend ECA such as participating in environment club and activities, visiting science museums, and utilizing out-of-school environments. In addition, curriculum developers, program developers, and authors should include the concepts of environmental perceptions, examples of environmentally-friendly behavior, environmental problems and their solutions, sustainability, and social perspectives to enhance environmental science curricula and books.

Finally, the development of quality environmental literacy education will depend on the quality of education and teacher training, quality of science curricula and textbooks in school systems, family engagement, as well as initiatives from environmentally sensitive governments and non-government organizations.

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Appendix 1: Questionnaire for Delphi Study (Step-I)

1. How would you define environmental literacy?
2. What are the sub-dimensions of environmental literacy over the next 20 years?
3. Which competencies (motivation, cognitive, social, and intention to action) should environmentally literate individuals have?
4. Who is responsible for the promotion of the development of a qualified environmentally literate individual?
5. What should be done to promote the development of a qualified literate environmental individual?
6. Which topics (concepts and contexts) should be included in the curriculum and textbooks that promote the development of environmental literacy?
7. Which teaching method(s) should be used to promote the development of qualified literate individuals?

2.1.2.2. Environmental Science, Technology, Engineering, and Mathematics Pedagogical Content Knowledge: Teacher's Professional Development as Environmental Science, Technology, Engineering, and Mathematics Literate Individuals in the Light of Experts' Opinions

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Abstract

This study is based on a Delphi study on environmental literacy which is related to both teachers professional development and environmental science, technology, engineering, and mathematics ($^{E+}$STEM) literacy. In the light of the expert opinions, the goal is to determine what teachers should do to develop their experiences and qualifications as $^{E+}$STEM literate individuals. In this study, a "mixed method" research design, in which both qualitative and quantitative methods are involved, is used to reveal the expert opinions. The exploratory sequential design, which is one type of mixed method research, is used. In the first step of the Delphi study, qualitative data are collected about teachers' professional development.

After analyses of data in the first step of Delphi study, the quantitative form is developed for second step of the Delphi study. Finally, after analyses of the data in the second step, the final quantitative form (3rd step) is prepared again. It is performed in three consecutive steps in Delphi study. The sample consists of the 45 experts who initially accepted to participate in the study. 20 of the 45 experts participated in the first step Delphi. The number of participants in the second and third Delphi study, respectively, is 44 and 26, respectively. It is concluded that there is a consensus about “having and updating content knowledge about environmental issues,” “following the development of environmental technologies, and applying them in class.” There is additional agreement about “having and developing pedagogical competencies for the development of teachers” experiences and qualifications as $^{E+}$STEM literate individuals. It is suggested that the concept of “environment” should be integrated into the framework of “STEM pedagogical content knowledge (PCK)” for teacher’s professional development. By this means, a new educational and environmental concept, $^{E+}$STEM-PCK, would be incorporated in teacher education.

Keywords: environmental science, technology, engineering, and mathematics literacy; Delphi study; mixed-methods; professional development; pedagogical content knowledge; stem education; science education

Introduction

In the 1990s, the National Science Foundation (NSF) began using "SMET" as shorthand for "science, mathematics, engineering, and technology;" however, this abbreviation has been changed to science, technology, engineering, and mathematics (STEM) since it causes conceptual confusion (Sanders, 2009). It is seen that the STEM concept, which is increasing in popularity in Europe nowadays, emerged as MINT in Germany. The term "MINT" is an acronym for "mathematics, information technology, science, and technology" (Wood, 2011). While STEM education has been around for a long time, it is the importance of this concept that has been emerged recently for legislators and educational administrators (White, 2014).

Importance of STEM Education in Science Education

STEM education is increasing in its importance as one of the main concepts in science education. STEM is an ever-growing part of our life. When it is examined the events and things that occur in our daily lives, it is seen that these are related to STEM. Therefore, some educators believe that individuals might be better for jobs in STEM fields with STEM education (Brown et al., 2011). STEM education has the opportunity to integrate four disciplines into coherent teaching and learning paradigm, as well as, providing students with the best opportunities to make sense of the world holistically (Lantz, 2009). STEM education is also important for the development of individuals. STEM education offers students the opportunity to realize their own potential, improve and strengthen self-efficacy, and STEM education supports them through their social and academic integration (Elster, 2014). Moreover, STEM education focuses on students' development of the following abilities (Flanders State of Art, 2018):

- Awareness of each component in STEM,
- Problem-solving activities,
- Researching and designing in a skilled and creative manner,
- Thinking and reasoning, modeling and abstracting,
- Strategically using and developing technology,
- Acquiring an insight into the relevance of STEM,
- Obtaining and interpreting information and communicating about STEM,
- Cooperative learning and teamwork,
- Acquiring 21st-century skills,
- Developing innovation skill.

Today, many countries continue to make reforms both in industry and education to address the needs of the world. In the area of science education, one of the reforms is to STEM education. Policymakers believe that STEM education is one of the concepts that is important for the industrial sector to improve the quality of the workforce. While the quality of the workforce is enhanced with STEM education, we should also pay attention to the environmental literacy to help conserve natural resources.

Environmental Literacy as a Core Concept in Science Education

Throughout its development, environmental literacy has been a key concept in science education. Studies on an environmental literacy framework have increased in recent years. In the Belgrade Charter (1975), environmental education had six components including: awareness, knowledge, attitude, skills, evaluation ability, and participation. According to the

Tbilisi Declaration (UNESCO, 1977), environmental education included: knowledge, attitude, skills, and participations. With the development of environmental education, the concept of environmental literacy was clarified, and it had four major components: knowledge, skills, affects (sensitive and attitudes), and behavior (personal investment, responsibility, and actions). Whereas, in the light of PISA data, Kaya and Elster (2017a, 2017b) propose that the concept of environmental literacy involves awareness and responsibility towards the environment and the development of environmental behaviors.

EE Objectives (Belgrade Charter, 1975)	**Tbilisi Declaration for EE (UNESCO, 1977)**	**Environmental Literacy (Roth, 1992)**	**Environmental Literacy (Kaya and Elster, 2017b)**
Awareness Knowledge	Knowledge	Knowledge	Environmental Awareness
Attitude	Attitude	Sensitivity, Attitudes and Values, Personal Investment and Responsibility	Environmental Responsibility
Skills Evaluation ability	Skills	Skills	Development of Environmental Behavior
Participation	Participation	Active involvement	

Figure 1: Components of environmental education and literacy (Adapted from Kaya and Elster, 2017b)

Based on the historical development of environmental literacy, environmental literacy is "basically the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems" (Roth, 1992, p. 10). According to Minner and Klein (2016), environmental literate individuals are able to understand ecosystems and how they function, able to think critically about effects of humans on ecological function and environmental problems, aware of the importance of natural phenomena and biodiversity in natural settings, and able to participate in action planning for themselves and their community to tackle environmental issues.

In another definition, environmental literacy is described as "the ability to make informed decisions about issues affecting shared natural resources while balancing cultural perspectives, the economy, public health, and the environment" (North Carolina Department of Environmental Quality, 2017, p. 7). Moreover, environmental literacy "involves an awareness and knowledge of the interrelationships among life forms and natural systems; understanding of ecological, social, economic, and cultural processes and issues; and knowledge and skills needed to make informed decisions and to become environmental stewards" (Tennessee Department of Environment and Conservation, 2012, p. 1). In a similar definition, environmental literacy is seen as "an individual's understanding, skills, and motivation to make responsible decisions that consider his or her relationships to natural systems, communities, and future generations" (Oregon Environmental Literacy Plan, 2010, p. 4).

Consequently, the literature review shows there is no universally accepted definition of environmental literacy (Loubser, Swanepoel & Chacko, 2001; Morrone, Mancl & Carr, 2001; Gayford, 2002). Even though the concept of environmental literacy has been used for many years, it is difficult to explain due to its complexity (Kaya and Elster, 2017b). Nevertheless, there is a need for further research on the framework of the concept and its application in the curriculum to meet present and future expectations. Therefore, it is necessary to reveal the framework of environmental literacy based on expert opinions.

Significance of 'Environmental STEM ($^{E+}$STEM) literacy' in Science Education

Asunda (2012) argues that there is the need for a high-quality STEM educated workforce for our 21st-century economies. These developing economies create pathways for a wide range of interesting and exciting career opportunities. The aim of STEM is to have knowledge in science, technology, mathematics, and engineering to achieve STEM literacy (Asunda, 2012). STEM literacy is important for individuals who will enter the labor market, as it is one of the core competencies of twenty-first-century workers (Techakosit, 2018). Therefore, STEM literacy first requirement is to have an interest and basic understanding of STEM-related fields (Sutter, 2014). The purpose of STEM is (Zollmann, 2012):

- to resolve societal needs for new technological and scientific advances;
- to resolve economic needs for national security and
- to resolve personal needs to become a fulfilled, productive, knowledgeable citizen.

To meet these goals, STEM literate individuals are able to describe, explain, and predict the outcome of natural phenomena, comprehend scientific articles and pieces presented in popular press and media, as well as have the ability to form their own opinion about the validity of scientific claims being made in the press and media (Sutter, 2014).

Nowadays, content of STEM is continuously widening. Therefore, STEM includes not only science, technology, engineering, and mathematics, but also the environment, economics, and medicine (Zollman, 2012). In this study, 'environmental STEM literacy' concept is used to emphasize the importance of relationship between environment and STEM literacy. A fundamental background of environmental STEM literacy is both environmental and STEM literacy. Environmental STEM literacy is:

- to have basic knowledge on environmental issues and STEM-related fields,
- to understand the integration of environmental into STEM fields,
- to deal with environmental issues or problems with an interdisciplinary (Science, Technology, Engineering and Mathematics) point of view and try to find solutions in the matter,
- to have the skills to evaluate data and draw conclusions to form one's own opinion.

Addressing the needs for a high-quality STEM workforce in future industries might be based not only on STEM literacy but also on environmental literacy. Therefore, environmental literacy should be integrated into STEM fields, as well as into STEM education.

Why do we need the 'environmental' in the STEM Education?

It is predictable that technology will develop faster with the industry 4.0 revolution. This means, unfortunately, that existing natural resources may be exhausted. Therefore, future generations should be aware of the necessity of environmental protection while developing and using technology. This awareness may contribute to the reduction of daily waste as well as commercial waste especially industrial waste (such as waste batteries, electrical and electric materials, etc.). For example, in Germany, it has been reported that the total amount of waste is increasing continuously especially since 2012 (Federal Ministry for the Environment, 2018). Preventing the continuous increase of waste means the protection of existing resources. We have the obligation to educate future generation as environmentally conscious individuals, taking into consideration the harms that science and technology have on the environment (Aydeniz, 2017). For this reason, the importance of 'environment' in

STEM education should be revealed. Teachers and researchers have a great responsibility in this regard because, during STEM education, it is necessary for practitioners to reveal the importance of the environment and how to integrate the environmental issues into STEM education.

The effect of pedagogical content knowledge and teachers' professional development

Teachers' professional experience, teaching skills, and disposition influence the training of qualified environmentally literate individuals (Kaya and Elster, 2018). In general, teachers gain their professional experience in a process that begins with pre-service training and continues with in-service training (Kaya and Gödek, 2016). Educators should focus on teacher training and professional development so that teachers can comfortably teach and integrate environmental subjects in their classes (National Environmental Education Advisory Council, 2015). It may not be possible to educate individuals with 21st century skills without the contribution of a qualified teacher (Pacific Policy Research Center, 2010). Moreover, professional development needs a multi-level approach to educate effectively students for environmental literacy (Ever, 2012). Institutions with responsibilities for teacher training and professional development should support the development of teachers' environmental content knowledge, pedagogical skills, interdisciplinary work, teaching approaches, effective assessment practices, and ability to use innovative technology. Therefore, the concept of Pedagogical Content Knowledge (PCK) introduced by Shulman (1986) remains important (see Figure. 2). In the view of Shulman (1986), PCK:

> goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching. … Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages

and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (p. 9)

PCK is influenced by three different component knowledge areas: subject matter knowledge, pedagogical knowledge, and knowledge of context (Abell, 2007).

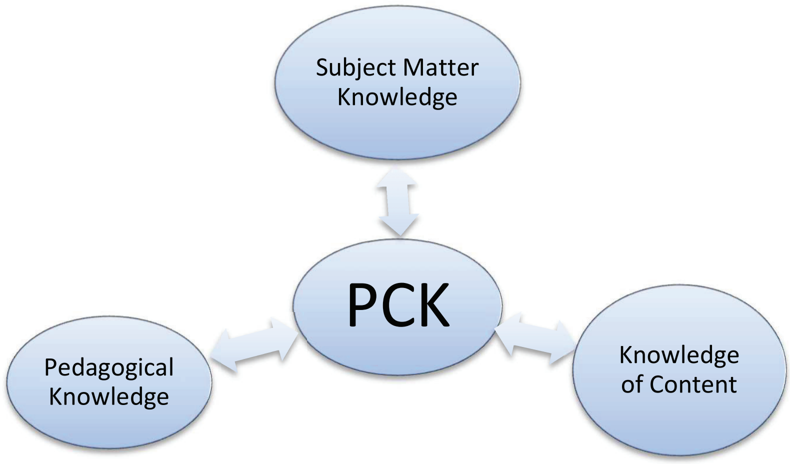


Figure. 1. The model of teacher knowledge. In this model PCK is presented as a unique knowledge domain (van Dijk, and Kattmann, 2007, p.889).

The development and change of PCK and its framework continue to meet the expectations of the 21st Century and beyond. One of the most concrete examples is Technological Pedagogical Content Knowledge (TPCK) introduced by Mishra and Koehler in 2006, which integrated technology with PCK and recognized the importance of technology in education (in figure 2) (Koehler and Mishra, 2009). TPCK is a structure formed by combining 3 different knowledge components: Technological knowledge, Pedagogical Knowledge, Content Knowledge, in the view of Mishra and Koehler (2006:10299), TPCK

> *is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that*

use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.

The development of by teachers is critical to effective teaching with technology (Koehler, Mishra and Cain, 2017). Because, TPCK is a beneficial concept for thinking about the integration of technology into teaching and how they might develop this knowledge (Schmidt, Baran, Thompson, Mishra, Koehler and Shin, 2009).

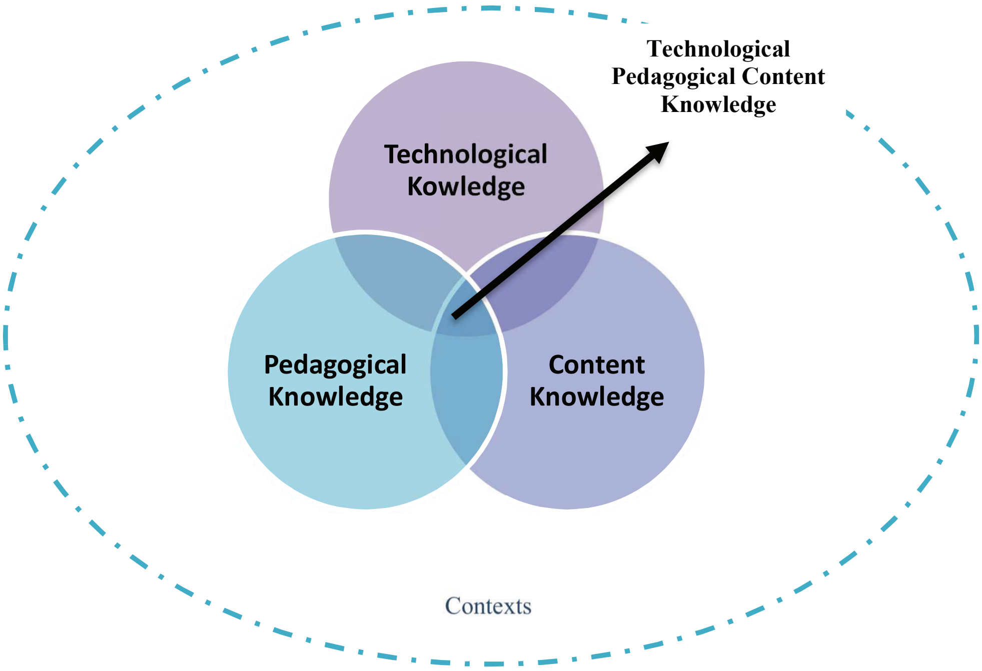


Figure 3: Technological Pedagogical Content Knowledge (Koehler ve Mishra, 2009:63)

Nowadays, stakeholders of education should think critically about how to integrate STEM education into science teaching with the concept of STEM starting to take place in the current science curriculum. For this reason, the importance of the relationship between STEM and PCK has emerged for fostering teachers' professional development.

Why do we need the integration of the STEM concept into the PCK?

Pedagogical knowledge is used to facilitate effective teaching practices in ways that aim to make learning more accessible to students (Hudson, English, Dawes, King and Baker, 2015). When pedagogy is most successful, faculty and students work together toward the shared purpose of learning (Association of American Universities, 2018).

One of the things to be aware of for the quality of STEM education is teacher education. The quality of the teacher education directly affects the teaching process. Teacher content knowledge is one of the paramount elements of the improvement of teaching and learning (Ball, Thames, and Phelps, 2008). However, teacher education programs rarely connect content instruction with pedagogy, furthermore, if teacher candidate is not specializing in a STEM-related field, STEM content preparation in pre-service training tends to be inadequate (York, 2018). Therefore, teacher are supported to increase their experience in STEM teaching and learning not only in pre-service but also in in-service training. Therefore, governments support educators'/teachers' knowledge and expertise in STEM disciplines through recruitment, preparation, support, and retention strategies (U.S. Department of Education, 2017).

Firstly, in order to increase the knowledge and experience of teachers and educators in STEM teaching, STEM concept should be integrated into the PCK. Saxton, Burns, Holveck, Kelley, Prince Rigelman and Skinner (2014) offer the concept of 'STEM PCK" and they mention that purpose of STEM PCK is to focus on student thinking about and useful strategies for teaching related to STEM topics. The term "STEM-PCK", an acronym for scientific, technology, engineering and mathematic pedagogical content knowledge.

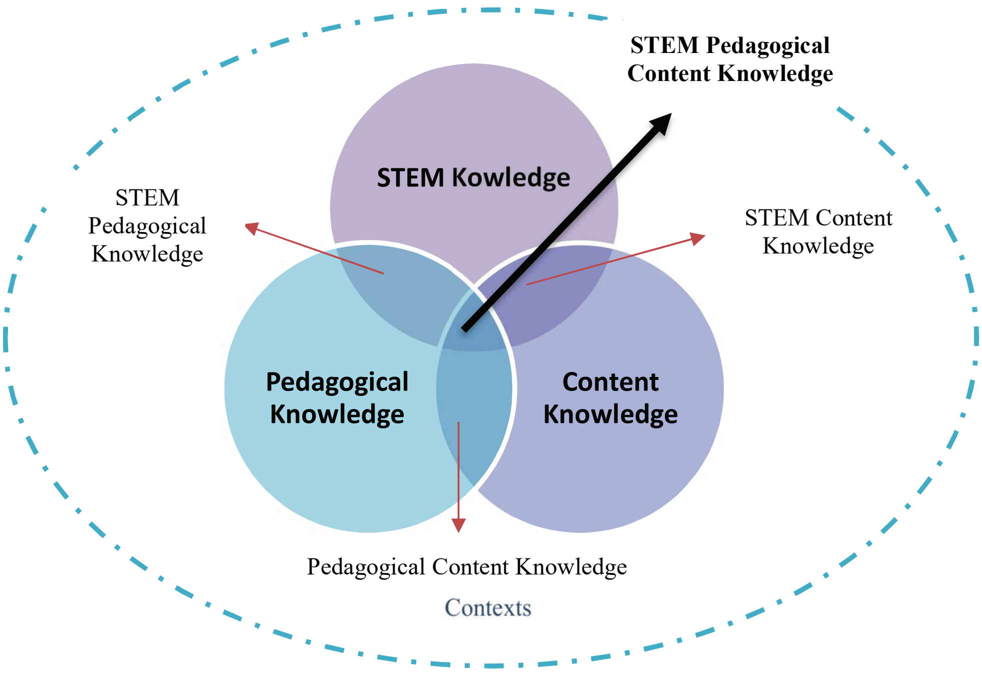


Figure 4: STEM Pedagogical Content Knowledge (Adapted from: Koehler and Mishra, 2009)

A good structure of STEM PCK ensures that teachers have the necessary knowledge to identify and measure their students' development of concepts related to STEM, inquiry-based processes, and real-world connections to alter intentionally their instruction in productive ways (Allen, Webb, and Matthews, 2016).

Research Questions

In this study, the main goal of the research is to determine teachers' experiences and qualifications as environmental STEM literate individuals for the development of environmental literacy in accordance with expert opinions.

- What teachers should do their experiences and qualifications as environmental STEM literate individuals for development of environmental literacy?

Research Methods and Design

In this study, a mixed method research design was used to reveal expert opinions about the concept of environmental STEM literacy. This type of research design combines qualitative and quantitative data (Creswell, 2014), which provides a more comprehensive coverage of the research topic (Conti, 2012). The exploratory sequential design, a type of mixed method research, was used. Through the exploratory sequential design, the results of qualitative research are the basis for subsequent quantitative research (Creswell, Klassen, Plano Clark, and Clegg Smith, 2011).

Based on expert opinions, the Delphi technique was utilized to determine the concept of environmental literacy and to develop the competencies of the environment literate individual. The Delphi technique is used for the collection of views on a specific topic (Villiers, Villiers, and Kent, 2005). It is a research technique used to obtain a common result using expert opinions to solve a complex problem (Aydin, 1999). This technique usually involves consecutive questionnaires directed to experts (Gencturk and Akbas, 2013) and allows them to explain their opinions freely without being influenced by the views of others (Ashmore, Flanagan, McInnes, and Banks, 2016). In the Delphi technique, qualitative, quantitative, or mixed method research can be utilized (Skulmoski Hartman, and Krahn, 2007). Therefore, the combined use of both the mixed method and the Delphi study techniques helps to uncover, define, and reach consensus on the best practices and specific situations for the research topic (Conti, 2012).

Process of the Delphi Study

The Delphi technique prevents participants' direct discussion with each other, and through interviews or questionnaires, participants can question the situation repeatedly (Dalkey and Halmer, 1963). It is used as a means of providing consensus among experts in situations where there are differences of opinion (Şahin, 2001). In this study, the Delphi study was carried out in three steps as seen in Figure 5. Each round contained the data collection tool, the collection of data, and the analysis of the collected data.

In this study, the Delphi study was performed in three consecutive steps. First, the qualitative data was collected. After the analyses of the data, the quantitative form was developed for the second step of the Delphi study. After the analyses of the data collected in the second step, the final quantitative form (for the third step) was prepared.

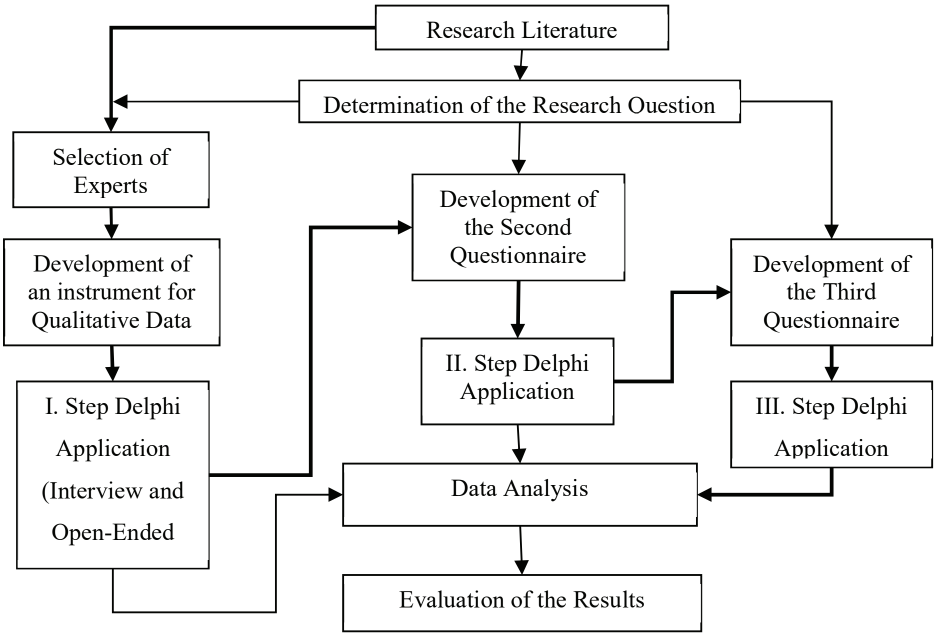


Figure 5: Process of the Delphi Study

The development of questionnaire forms and data analysis methods are structured according to the three steps (Schulte, 2017). However, in the Delphi method, qualitative data from the first round is obtained, and then this data provides the basis for the quantitative data in both the second and third rounds (Cartwright, 2014).

Sample

It is performed in three consecutive steps in Delphi study. The sample consisted of 45 experts who volunteered to participate in the study. These 45 experts have PhD degrees related to environmental education and were selected by using purposive sample method. These experts work as a scientist/an educator/a teacher in the European Union (40), the United States and Africa (5). The numbers of the participants in the 1st, 2nd, and 3rd Delphi study steps were 20, 44, and 31, respectively.

Data Analysis

To understand whether consensus had been reached statistically, the mean (($\overline{x}$)), standard deviation (sd), median (med), difference between quarters (DBQ), responses %, consensus (cons), consensus difference (cons. dif.) were recorded. These results are presented in the Results' Table 2.

Results

The results obtained at the end of the first round were used in both the 2nd and 3rd rounds. Each question represents each theme and each item represents each code.

Table 1.: Views on how teachers to develop their experiences and qualifications as environmental literate individuals (Qual.)

Thema	Code	N
Responsible of teacher as environmental literate individuals	To have content knowledge about environmental issues	3
	To have pedagogical competencies to teach about the environmental issues.	3
	To update their knowledge about environmental issues	2
	To apply the technology related to environment (nanotechnology and environmental technologies etc.)	1
	To follow the development of the environmental technologies	1
	To develop their competencies for teaching environmental topics.	1

In the interviews and questionnaires, some questions were asked to determine the experts' views on how teachers develop their experiences and qualifications as environmental STEM literate individuals. The majority of experts believed that 'Teachers should have content knowledge about environmental issues and have pedagogical competencies to teach about the environmental issue' (see Table 1).

Table 2: How teachers should develop their experiences and qualifications as environmentally literate individuals

Item	Round	$\bar{x}$	sd	Med	DBQ	Responses %			Cons	Cons. Dif.
						5-7	4	1-3		
Teachers should have content knowledge about environmental issues	**2.R.**	6.56	0.63	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.77	0.50	7.00	0.00	100	-	-	**Yes**	
Teachers should constantly update their knowledge about environmental issues	**2.R.**	6.63	0.66	7.00	1.00	97.6	2.4	-	**Yes**	2.4
	3.R.	6.77	0.50	7.00	0.00	100	-	-	**Yes**	
Teachers should follow the development of environmental technologies	**2.R.**	6.34	0.88	7.00	1.00	97.6	-	2.4	**Yes**	2.4
	3.R.	6.45	0.77	7.00	1.00	100	-	-	**Yes**	
Teachers should apply technology related to the environment (nanotechnology, environmental technologies, etc.)	**2.R.**	6.12	1.15	7.00	1.50	91.8	4.9	4.9	**Yes**	-1.8
	3.R.	6.13	1.01	6.00	1.25	90.0	10.0	-	**Yes**	
Teachers should have pedagogical competencies to teach about environmental issues	**2.R.**	6.54	0.75	7.00	1.00	97.6	2.4	-	**Yes**	-0.6
	3.R.	6.68	0.70	7.00	0.00	96.8	3.2	-	**Yes**	
Teachers should consistently develop their competencies for teaching environmental topics	**2.R.**	6.61	0.63	7.00	1.00	100	-	-	**Yes**	0.0
	3.R.	6.71	0.59	7.00	0.00	100	**-**	**-**	**Yes**	

$\bar{x}$: mean; sd: standard deviation; med: median; DBQ: difference between quarters; Cons: consensus; Cons. Dif.: consensus difference between the second and third round analysis; responses: 5-7: weakly to strongly agree; 4: neutral; 1-3 strongly to weakly disagree

As seen in Table 2, at the end of Delphi study, there was a consensus on six items about how teachers should develop their experiences and qualifications as environmental STEM literate individuals. When 2nd and the 3rd Delphi results were compared, the percentage of ‘teachers should constantly update their knowledge about environmental issues and follow the development of environmental technologies' increased, however, the percentage of 'teachers should apply technology related to the environment' decreased.

Discussion

Teaching skills and a teacher's disposition are important for the development of qualified environmentally literate individuals (Kaya and Elster, 2018). Therefore, it is necessary to focus on teacher training and professional development (National Environmental Education Advisory Council, 2015). It was concluded that there was a consensus about 'having and updating content knowledge about environmental issues', 'following the development of environmental technologies, and applying them in class.' There was additional agreement about 'having and developing pedagogical competencies for the development of teachers' experiences and qualifications as environmental STEM literate individuals. Experts believe in the importance of teachers' having knowledge about the pedagogical knowledge as well as environmental knowledge and updating them. In particular, science teachers should update their pedagogical content knowledge and their experiences in the light of the increasing importance of STEM education. A robust STEM PCK ensures that teachers have the necessary knowledge to identify and measure their students' development of concepts related to STEM (Allen, Webb, and Matthews, 2016). With STEM-PCK, teachers have knowledge of both the environment and STEM and gain experience in how to integrate these two concepts into each other. By this means, science education might meet expectations of present and future generations.

On the other hand, it is thought that the concept of STEM education will be more specifically addressed for more qualified and specific STEM education. The framework of 'Science' in STEM is very broad. For this reason, it may be predicted that new nomenclature related to STEM will increase to develop the applications that reveal the specific relation of the different branches of science. Else, adding different and new dimensions (such as in art) to STEM education, it is possible to try to reveal the importance of new dimension added in STEM education (such as Science-Technology-Engineering-Art-Mathematics), as well as its framework widened (STEAM education).

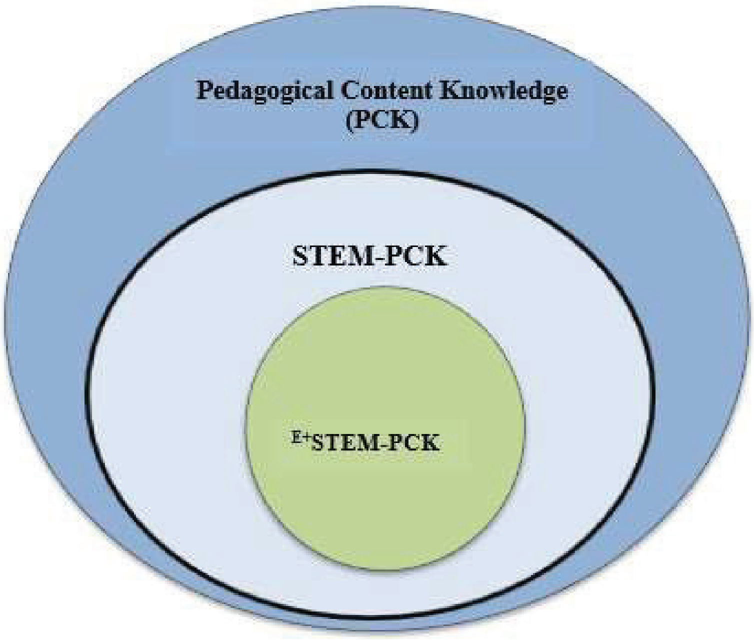
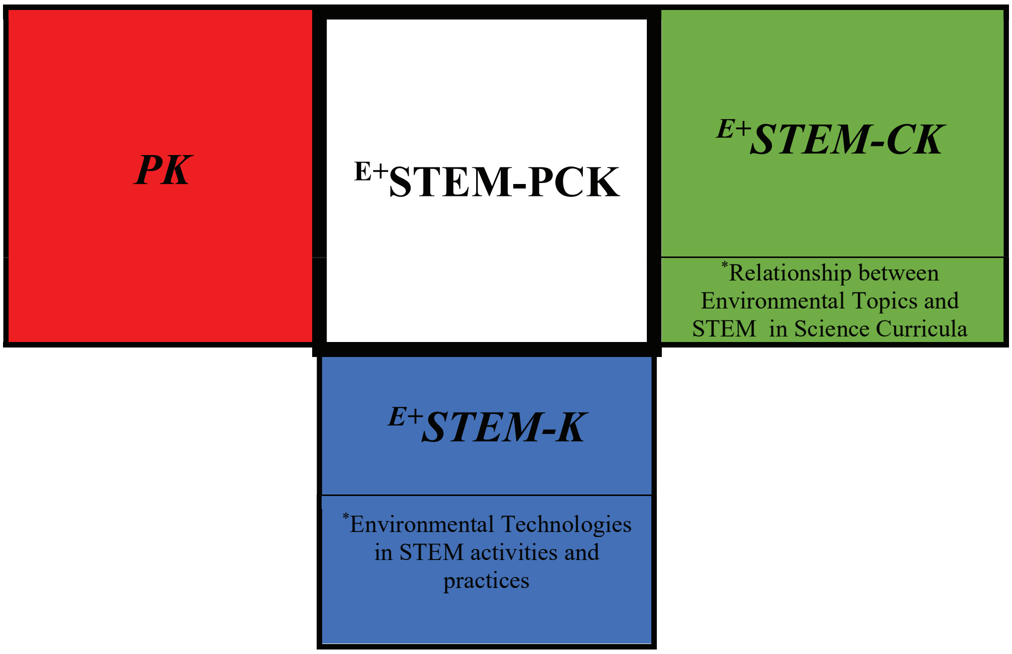


Figure 6: Integration of environmental into the STEM

For instance, between 2011 and 2015, The Korean government decided to include STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in education policy (The Korean Ministry of Education, Science and Technology, 2011, as cited Hong, 2017). Another example, The National Science Foundation has integrated concept of computing into the STEM education (STEM+C) (National Science Foundation, 2018). The other example is the attempt to integrate the concept of the environment into the framework of the STEM in this study (as seen Figure 6).

Conclusion and Recommendations

The results show teachers' professional development is a key factor that promotes the development of environmental STEM literate individuals. Thus, qualified environmental STEM literate individuals require qualified environmental STEM literate teachers. Additional environmental education should become part of the academic teacher training programs in universities. In particular, the concept of 'environment' should be integrated into the framework of STEM-PCK for teacher's professional development (see Figure 7). The determination of Environmental STEM Pedagogical Content Knowledge ($^{E+}$STEM-PCK) includes three different knowledge components: **$^{E+}$STEM-Content Knowledge** (knowledge on STEM and Environment), **Pedagogical Knowledge** (knowledge on how to teach environment-related STEM activities), **$^{E+}$STEM-Knowledge** (disciplinary knowledge required for the integration of science, technology, engineering and mathematics as environmentally friendly, in additional knowledge of the relationship between the environment and the subjects to be taught about STEM).



Note: When colors of blue, green and yellow are mixed, the white color occurs.

Figure 7. Components of E+STEM pedagogical content knowledge for science teaching

In this figure 7, teachers' knowledge, which is equally important, has 3 core components. Shulman (1986) described the combination knowledge of pedagogy and content as pedagogical content knowledge. In this paper, it is described the combination knowledge of pedagogy, content (not only fields of STEM but also environment), and associating disciplines with each other (in figure 8).

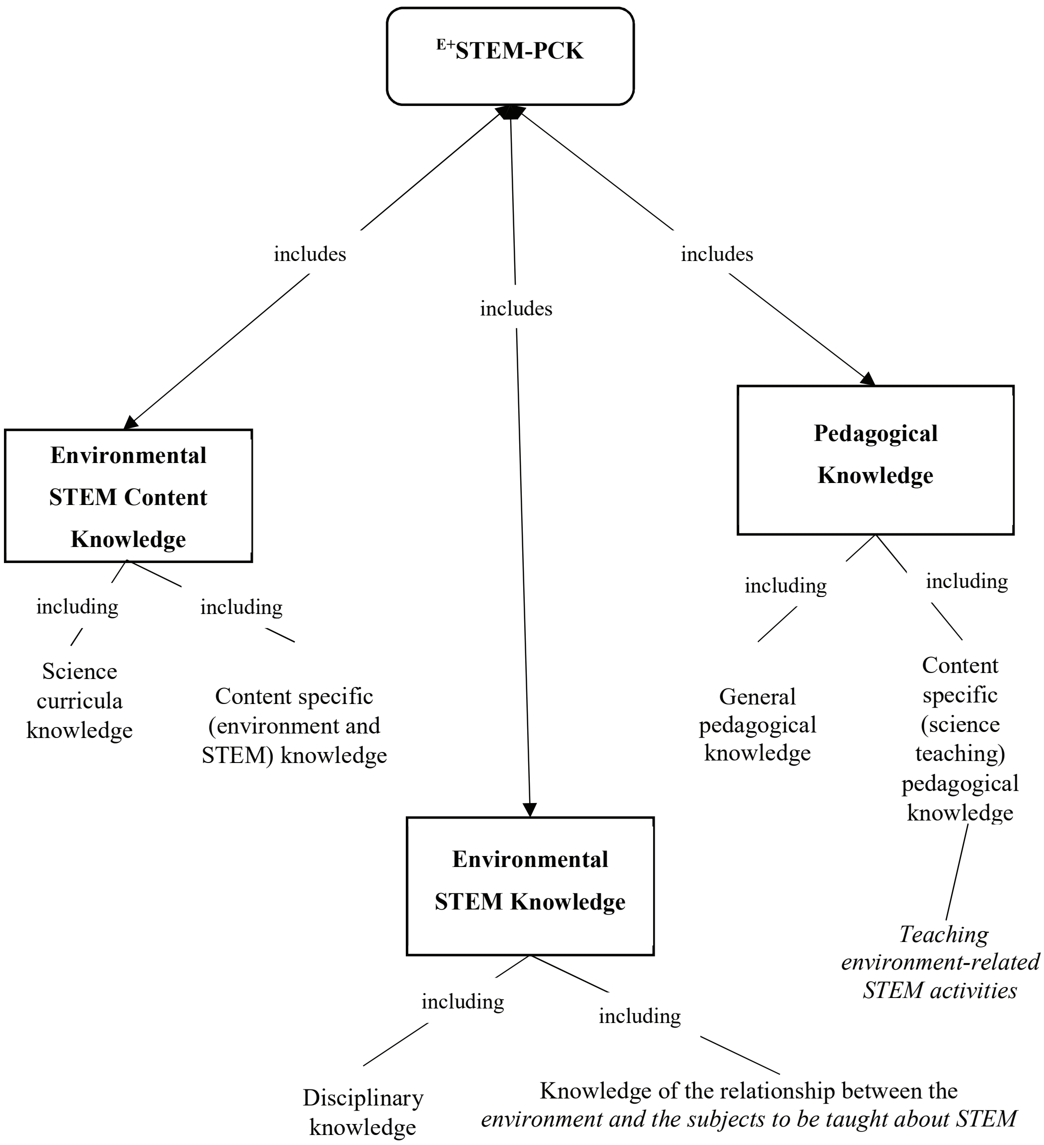


Figure 8. Environmental STEM PCK and its components

By this means, a new educational and environmental concept, E+STEM-PCK, would be incorporated in teacher education. Then, future research might determine the scope of E+STEM-PCK in the light of framework of PCK and STEM-PCK and how it can be taught to teachers, thereby increasing the quality of STEM education. In addition, the concept of ‘environment’ should be integrated into the framework of STEM education allowing an evolution to environmentally conscious STEM education (E+STEM) in science classes and curricula.

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Mixed Research Method, March 2018 Barcelona/SPAIN

***MAXQDA*, ** February 2018, Bremen/GERMANY

***Scienctific Publications for Natural Scientists*, ** February 2018, Bremen/GERMANY

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Project Presentation

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THE DOCTORAL DEGREE REGULATIONS IN GERMAN

Versicherung an Eides Statt

Ich, ________________________________

(Vorname, Name, Anschrift, Matr.-Nr.)

versichere an Eides Statt durch meine Unterschrift, dass ich die vorstehende Arbeit selbständig und ohne fremde Hilfe angefertigt und alle Stellen, die ich wörtlich dem Sinne nach aus Veröffentlichungen entnommen habe, als solche kenntlich gemacht habe, mich auch keiner anderen als der angegebenen Literatur oder sonstiger Hilfsmittel bedient habe.

Ich versichere an Eides Statt, dass ich die vorgenannten Angaben nach bestem Wissen und Gewissen gemacht habe und dass die Angaben der Wahrheit entsprechen und ich nichts verschwiegen habe.

Die Strafbarkeit einer falschen eidesstattlichen Versicherung ist mir bekannt, namentlich die Strafandrohung gemäß § 156 StGB bis zu drei Jahren Freiheitsstrafe oder Geldstrafe bei vorsätzlicher Begehung der Tat bzw. gemäß § 161 Abs. 1 StGB bis zu einem Jahr Freiheitsstrafe oder Geldstrafe bei fahrlässiger Begehung.

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Ort, Datum Unterschrift