Developing an Environmental Knowledge and Attitude Instrument to Measure Students' Environmental Literacy in the Australian and Korean secondary school science contexts

Master of Research (MRes)

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TABLE OF CONTENTS

DECLARATION

I hereby declare that this thesis has not been previously submitted to any other institution or university for a higher degree. Except where otherwise acknowledged, this thesis is comprised entirely of my own work.

Ethical aspects of this research have been approved by the Macquarie University Human Research Ethics Committee (HREC Reference No. 52019557610317).

(Signed)____________________________________ Date: 8/11/2019

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ABSTRACT

This study aims to develop the Environmental Literacy Test for Secondary School Questionnaire (ELTSQ) to assess secondary Australian and Korean students' environmental literacy (EL) in science classrooms.

To construct the environmental knowledge (EK) questionnaire in the ELTSQ, environmental education (EE)-related content outcomes in the science curriculum/syllabus were selected and analysed using Revised Bloom's Taxonomy (RBT). The analysis found that most of the EE content outcomes were grouped under *Understand*/ *Conceptual* categories in both Australia's New South Wales state (NSW) and Korea. No *Create* category in the cognitive process dimension was found. The Environmental Attitude (EA) questionnaire in the ELTSQ was prepared based on collecting items from the New Ecological Paradigm (NEP) questionnaire and existing attitudes questionnaires.

The ELTSQ was distributed to a total of 380 Korean secondary students. The EK and EA scales showed high Cronbach alpha reliability. All mean percentage of correct answer/responses in EK and EA scale are all-around 50 %. The *t*-test results revealed that there was a significant difference between students in Years 7–8 and Years 9–10 in the EK scale, but no significant school-year differences in the EA. For the correlation between EK and EA, they were significantly and highly correlated with each other.

In conclusion, the developed ELTSQ has shown the ability to measure Korean secondary school students' EK and EA in science contexts.

CHAPTER 1 : INTRODUCTION

1.1 Need for research

This study aims to develop an assessment instrument to measure secondary school students' environmental knowledge (EK) and environmental attitudes (EA) in the science classroom context. Previous research studies exist that have investigated the knowledge of and attitudes towards the environment and the explicit connection between environmental education (EE) and science education (SE) by interrelating with cognitive and affective perspectives in science curriculum (Dunlap, 1998; Gurevitz, 2002; Hollweg et al., 2011; Stern et al., 1995; Yount et al., 1992).

SE has been an essential part of developing the understanding of concepts relating to environmental issues and ecology, thus enhancing students' pro-environmental behaviour and positive attitudes towards the environment. Volk (1984) has emphasised that the purpose of SE and EE is to educate all citizens to make their own life decisions about how they should take personal responsibility for the environment/social issues. There have been continuous efforts in SE to integrate EE into science teaching. STSE (Science, Technology, Society and Environment) model has been used as a curriculum development approach to encourage young students' critical thinking more clearly and firmly in their daily lives (Zhang et al., 2017). The author emphasised that SE and EE are co-linked with each other because people believe that science and technology provide the most effective approach for environmental protection and improvement (Barrett & Pedretti, 2006; Hodson, 2009; Zhang et al., 2017). Active EE integration has been continuously improved and taken into consideration in terms of STEM/STEAM curriculum development approaches (Bekir & Mahmut, 2016). *The North American Association for Environmental Education* (NAAEE) currently integrates EE into E-STEM (Science, Technology, Engineering, and Math) learning for youth: for example, Building a framework for connecting young children to nature and the environment through education by assessing early childhood STEM-related resources (Kunkle, 2018).

To equip students as global citizens, the United Nations Environment Programme (UNEP) has proposed an educational framework consisting of knowledge, skills, values, and experiences that will encourage students' commitment to resolved present and future environmental problems (UNEP, 2003). Based on this environmental sustainability framework, environmental programs for schools have been assessed and selected by researchers and educators for implementation in both formal and informal educational setting. For example, international Eco-schools program has been selected by over 51,000 'eco-schools' across 68 nations *(http://www.ecoschools.gobal; http://www.eco-schools.org.au)*.

The New South Wales (NSW) Department of Education and Training in Australia has announced its strategy for *Implementing the Environmental Education Policy in your School*, recommending that schools integrated EE into the school curriculum to develop the students' knowledge, skills, attitude, and behaviour (NSW-DET, 2001).

In Korea, the Environmental Education Promotion Act was enacted in 2008 (Act No. 8949, 2008), defining EE as 'education to cultivate and practice knowledge, skills, attitudes, values to improve the environment promoting the sustainable development of the country and communities' (Lee et al., 2017, pp.8) and also actively integrated into the SE curriculum since the national curriculum in 2013 (MOE, 2013) started heading towards Arts-integrated STEM (STEAM). For example, climate change is one of the topics in secondary school science classrooms suited to the integration of EK, EA and skills to influence students' behaviour (Monroe et al., 2013). The integration of lessons on human impact on the environment with students' cultures and everyday life experiences has been woven into school program development (Lee et al., 2017). Korean science curriculum revised in 2015 national curriculum that included EE in the form of sustainable development education and also promoted the idea of students' enjoyment of SE as an educational goal, to be achieved by boosting the integrated EE within SE. Moreover, the new integrated science curriculum has focused on participation-based teaching and on learning system such as project-based learning result from the integration with environmental sustainability (Kwon et al., 2016, Lee et al., 2017, pp.10).

Taking into account the existing similarities and differences between the two countries in their integration of EE with science subjects, Australia and Korea were selected as the two sites for investigation of students' EK and EA. To Achieve this aim, the first step was to develop appropriate questionnaires through several steps of item validation: for example, content validation, expert validation, student interviews, and factor analysis.

1.2 Research questions

The specific research questions are:

1. How are the EE-related content outcomes organised in cognitive terms in Australian and Korean secondary science curricula?
2. Is the EL assessment tool valid and reliable for secondary school students?
3. What are the students' levels of EK and EA in Australia and Korean secondary students?
4. Is the current science syllabus influent to secondary school students' EK and EA?
5. What is the correlation between EK and EA in secondary school students?

1.3 Research objectives

The aim of this study was to assess students' EK and EA in both Australian and Korean secondary students by using appropriate EL questionnaires for adolescent in science class. To achieve this aim, the development of EL assessment tools is essential. Another aim is to develop the EL assessment tool. Science syllabus analysis, therefore, was carried out using Revised Bloom's taxonomy (RBT) which has been a useful tool to analyse curriculum to improve EK measurement tool. Newly developed new ecological paradigm (NEP) and Deposition, framed by NAAEE was used to measure students' attitude towards the environment. This study specifically investigates the impact of EE embedded in science programs on students' EL. It insists that this study represents the first attempt to assess EL in Australians and Korean secondary school-based science education.

1.4 Significance of the study

This study provides a unique insight into secondary students' EK and EA with a variety of data exploration about the environment. The significance of this research results includes the provision of more significant insights into the considerable efforts that provide directions to improve EE curriculum in Australian and Korean secondary science syllabus in the future. It has not sufficiently studied about the EL of secondary school students within the field of secondary science syllabus. These outcomes, however, will contribute an opportunity for educators and environmental scientists to analyse the EL of the curriculum by combining them with science subjects and further relevant policy discussion and decision-making, curriculum design and development to the improvement of EE. Moreover, the questionnaire uniquely designed based on national standard of EL, such as NAAEE framework, so that this EL assessment tool is eligible in other countries. Furthermore, the study will contribute to taking responsibility for the field of environmental behaviour.

1.5 Limitations of the study

There are a few limitations in the scope and depth of the research case. The research scope is small, pertaining only to the small number of participants to attend the assessment. Unfortunately, the outcomes from Australian (NSW) was not able to achieve in this study due to the lack of awareness of EE in school and rejected from many NSW schools due to that this research application evaluated as having no potential value in the school system and not directly familiar to school engagement. Only Korean participants were scaled to assess students' EL. However, it emphasised that this research is an initial validation process about the EL assessment for secondary school students.

The preliminary survey study was conducted as part of construct validation within little research time to apply large scale of EL assessment for further research to develop the precise assessment.

1.6 Definition of terms

Some concepts used in this research should first be defined.

Environmental Education (EE): EE refers to the overall field of education that engages learners with their environment (Smith, 2014, pp. xix).

Environmental literacy (EL): EL is initially defined as the knowledge and understanding of society's impact on the natural world and is one of the important concepts of the goal and evaluation of EE. EL has extended to definitions that implicate environmental knowledge, skills, belief and behaviours (Marcinkowski, 1995).

Scientific literacy (SL): SL denoted on crucial 'facts' of content that people should understand in the science disciplines, biology, chemistry, physics, geology and astronomy (Smith, 2014, pp.123).

Environmental knowledge (EK): EK, the component of EL, is defined as personal understanding on how environment; how human interacts with the environment; how environmental issues arise; and in how these environmental issues overcome (Abdullah et al., 2011, pp. 1,025).

Environmental attitudes (EA): EA, the component of EL, is defined as learned tendencies in the form of consistent behaviours against environment either positive or negative (Pelstring, 1997; Sadik et al., 2014, pp. 2,379)

Education for Sustainability (EfS): EfS is a process of learning where all learners are encouraged to think and act for change to address sustainability (Holdsworth & Hegarty, 2015; Lynch, 2017, pp. 5).

New Ecological Paradigm (NEP): NEP is a measure of endorsement of 'pro-ecological' worldview. It is used extensively in EE where differences in behaviour or attitudes are believed to be explained underlying values or paradigm (Anderson, 2012, pp.1).

Environmental Disposition (ED): In general, the definition of disposition is as the state to do something (Oxford English Dictionary, 1989). ED is to be defined the state of the individual to be sensitive both to the environment and the environmental issues and take ethical values of the society into deliberation while making decisions and showing responsibilities to the environment (Roth, 1992; Fettahlıoğlu et al., 2016, pp. 3,182).

1.7 Organisation of thesis

In this thesis structure, the construction and validation of EK and EA were conducted to assess both Australian and Korean secondary school students' environmental knowledge and attitudes by administering the EL questionnaire.

Chapter One is an introduction, together with a general background about EE and EL, historical information about the assessment of EL in schools. The chapter also contains the objectives, study's significance and the study limitations and suggest future implication for further study.

The Literature Review narrated in Chapter Two. This chapter includes a summary of the definition of EE and EL and their revolutionary concepts. Current EK and EA within the secondary science curriculum reviewed between Australian and Korean secondary science syllabus. The types of tools to measure the scale of EK and EA was also introduced based on their characteristics. The theoretical framework of the study described in this chapter.

Chapter Three described the designing of analyses to validate the EL knowledge and attitude questionnaires such as revised Bloom's Taxonomy (RBT) for content validation and Environmental Literacy Test for Secondary School Student Questionnaire (ELTSQ) and NEP for assessment of students' EK and EA.

Chapter Four presents the results from the use of the measuring instruments. The content analysis of EE related content outcomes in science syllabus compared between Australian and Korean school curriculum. The findings of the survey questionnaires were carried and analysed statistically within the quantitative and qualitative assessment for school students' EK and EA. This chapter also contains a discussion and argument about EL assessment and the relationship with EK and EA.

In Chapter Five, the conclusion from the study are drawn together with a summary of the study and future suggestions.

CHAPTER 2: LITERATURE OF REVIEW

In this chapter, general backgrounds of EE and EL, including their concepts and theoretical frameworks are reviewed, and their current implementations were literate by being related in science curricula. Especially, Environmental knowledge and attitudes are reviewed in terms of how they are co-related to the science curriculum.

2.1 Environmental education and science education

EE involves the relationship between humans and the environment, including both the natural and the human-made environment. EE emerged in the 1960s as the term for the educational dimensions of the environmental movement, which was concerned about air and water pollution, growth in world population, continuing depletion of natural resources and environmental degradation (Gough et al., 2010; UNEP, 2003). EE has been evolute with scientific knowledge to advance students' understanding about environmental issues and educated toward to educate students to become scientifically literate citizens who can make critical decisions and solve problems (Lee et al., 2015).

In science subjects, the EE primarily approached the cognitive section to develop knowledge and skills in environmental science that help students identify cause and effect relationships (Sauvé, 2005, pp. 17). Despite the effort to establish science curricula for environmental stainability, the relationship between EE and SE is still complicated in terms of scientific knowledge to become an environmentally responsible citizen. (Pedretti, 2014, p. 306; Hungerford & Volk, 1990).

In this chapter, the historical framework of EE and EL are reviewed and their current roles in science classes by the understanding of the value of EL in the field of EE program in Australian and Korean science curricula.

2.1.1 The evolution of the framework of environmental education

Environmental degradation and the decreasing quality of nature have become socially and ecologically severe concerns and have caused people to focus on environmental beliefs and attitudes since the industrial revolution in the late 19th and early 20th centuries.

During the 1960s and 1970s, a previous EE practice focused on nature studies and fieldwork to educate about plants and animals and outdoor activities as the physical systems (Palmer, 1998). More recent characterisations of EE have emphasised education for a sustainable future and have included creative and critical approaches to socio-ecological issues, eco-justice, long-term thinking, innovation, empowerment and the interconnectedness of environment, economy, society and technology (Pedretti, 2014, pp. 308). The international EE program was aided by the Belgrade International Environmental Education Programs at the UN conference held in 1975 and UNESCO-UNEP, the Tbilisi Intergovernmental Conference held in 1978 (Velempini, 2016, pp. 57). The Tbilisi Declaration (UNESCO, 1978, pp. 24) outlined a more comprehensive document on the goals, objectives, roles, characteristics, framework and guidelines of EE and suggested that 'education utilizing the findings of science and technology should play a leading role in creating awareness and a better understanding of environmental problems' (Ramdas et al., 2014, p. 381) and highlighted and described five categories of EE:

Awareness: acquiring awareness and sensitivity to the total environment and its allied problems.

Knowledge: gaining a variety of experience in and acquiring a basic understanding of the environment and its associated problems.

Skills: acquiring skills for recognising and solving environmental problems

Attitudes: acquiring values and a feeling of concern for the environment and motivations that enable involvement in improvement and protection of the environment

Participation: being actively involved at all levels in working towards solving environmental problems (Hungerford et al., 1980, pp. 45; Danis, 2013, pp. 3; Pedretti, 2014, pp. 306)

Since the establishment of the Brundtland Commission (Brundtland, 1987) in the World Commission on Environment and Development (WCED), which first published the definition of sustainability through the report in *Our Common Future*, EE has accentuated the concept of environmental sustainability (Aho, 1984; WCED, 1987; Tuncer et al., 2005). Much of the new impetus for comprehensive and holistic EE has come from Agenda 21, adopted at the Rio conference in 1992. Chapter 36 of Agenda 21, 'Promoting Education, Public Awareness and Training', calls for reorienting education towards sustainable development, increasing public awareness and promoting training (UNCED, 1992; UNEP, 2003, p. 4). Through successive UN meetings, EE has evolved over the last few past decades and has developed a controversial relationship with the more recently described area of education for sustainable development (Gough et al., 2010, pp. 1). In recent years, learning sustainability and its development have become a central strategy in EE, and new EE concepts have now emerged in schools, homes and public communities. The paradigm of EE goals and framework are listed in Table 2.1.

Table 2.1 The paradigm of international EE goals

Years	Goal of EE
1971-1980	UNESCO-UNEP set forth objectives of awareness, knowledge, skills, attitudes, evaluation and participation (UNESCO, 1978)
1981-1990	The emphasis of sustainable environmental education became focusing more attention on social equity, economics, culture and political structure (Brundtland, 1987)
1991-2000	To promote sustainable development and improve the capacity of the people to address environmental and developmental issues in the international action known as Agenda 21 (Earth Summit, UNCED, 1992)
2001-2010	To require and use knowledge, skills, values, experience and determination to solve present and future environmental problems (UNEP, 2003) To develop Good Life Goals to help support SDGs (UN environment, 2018)

SDG: Sustainable Development Goals

In school curricula, the origin of EE was to encourage the promotion of nature and outdoor learning in elementary schools and later to trace the conservation movement (Velempini, 2016, pp. 51). For example, Stevenson (2007) wrote that nature study became famous through the school camps movement in Australia (Velempini, 2016, pp. 51). EE has been perceived as both curriculum product and process. Although the curriculum content must be changed to include the knowledge and skills that are considered essential components of this area, it is also a learning method that involves changing attitudes, behaviours and social engagement. (Gough, 2010, pp. 1).

Education paradigm for EE has been discussed, using the approach of staying within the traditional curriculum. EE *about*, *in* and *for* the environment was first described by Lucas (1979). Education *about* the environment includes basic knowledge and understanding of the environment, which includes scientific theories, concepts and laws (e.g. learning the niche of different plants and animals). Education *in* the environment refers to using the environment as a resource with an emphasis both on planned inquiry and investigations that provide students with the opportunity to engage in first-hand personal experience (e.g., exploring beaver dams or species in a local wetland ecosystem), while education *for* the environment is concerned with values, attitudes and agency embedded within an ethical framework (e.g. participating in a campaign to preserve a local wetland ecosystem; Palmer, 1998; Pedretti, 2014, pp. 308). EE *in* the environment or *about* the environment became common in school curricula in the West in the 1970s and 1980s. EE *for* the environment and *with* environments developed more in the 1990s with the growth of socially critical education. This shift encourages the development of attitudes, behaviours and problem-solving skills to build responsible and committed individuals. Thus, EE has evolved over the past decades to have a contentious relationship with the more recently described area of ESD (Gough et al., 2010).

In the educational curriculum, disciplinary of EE has been discussed due to the complexity of its nature and its reliance on almost all other disciplines, such as science, math and geography (Hungerford & Peyton, 1994, pp. 7). Figure 2.1 shows the interdisciplinary model and the multidisciplinary model in EE curriculum development and implementation. In the interdisciplinary model, the approach is to refer to individual courses or series of courses, units or other curriculum packages as a single subject. The multidisciplinary model incorporates EE components into other established, interrelated disciplines in an infusion approach (Hungerford & Peyton, 1994). Both disciplinary models have advantage and disadvantages. Nowadays, new disciplinary called cross-disciplinary is enforced in EE program or environmental engineering science program with the benefit of contributing to the creation of the innovation in knowledge, skills and attitudes networking (Penttilä et al., 2019).

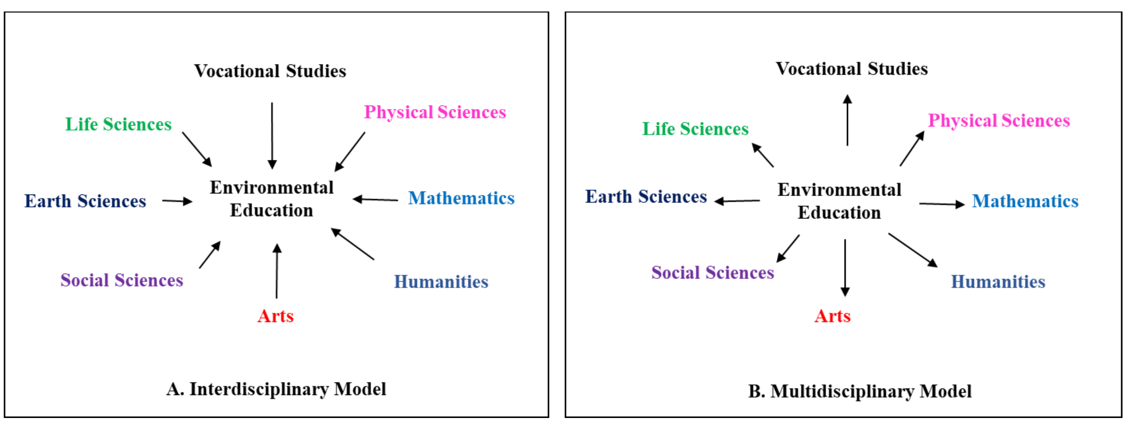

Figure 2.1 The interdisciplinary model and the multidisciplinary model (Hungerford & Peyton, 1994, pp. 9)

2.1.2 The evolution of framework of environmental literacy

The term '*environmental literacy'* was first used 45 years ago in an issue of the *Massachusetts Audubon* by Roth (1968), who inquired 'How shall we know the environmentally literate citizen?' The definition of EL has been reviewed, and it has been suggested that it should be based on an ecological paradigm, which includes interrelationships between natural and social systems (O'Brien, 2007, pp. 8). Simmons (1995), of the North American Association for Environmental Education (NAAEE), reformed the components of EL in the development of the National Project for Excellence in EE. The defining term has evolved and been extensively reviewed (e.g., Simmons, 1995; O'brien, 2007; McBride et al., 2013, pp. 67). Simmons (2007, pp. 5-6) introduced seven major components of EL: affect, ecological knowledge, socio-political knowledge, knowledge of environmental issues, skills, environmentally responsible behaviours, and determinants of environmentally responsible behaviours. Roth (2002) also extended the definition of EL with a set of understandings, skills, attitudes and mind habits that enable individuals to relate to their environment positively and in their long-term behaviour (O'Brien, 2007, pp. 5).

Frameworks of EL proposed over the past decades have shown a high level of similarity and correspondence in their main components (McBride et al., 2013, pp. 67). Table 2.2 shows that most frameworks include ecological knowledge, environmental sensitivity, environmental issues, and skills/attitudes and behaviour to prevent or resolve environmental problems. The National Environmental Education Advisory Council (NEEAC) in its 2005 Report to Congress declared a national assessment of EL (NEEAC, 2005; McBeth & Volk, 2010, pp. 56). NAAEE defines a new framework of EL by organising various measures of knowledge and understanding concerning environmental concepts, problems and issues, cognitive and affective dispositions, competencies, and appropriate behavioural strategies (Figure 2.2; Hollweg et al., 2011). The conceptual framework of this study was based on the recent strands of EL provided by NAAEE to explore the EL of high school students.

Table 2.2 Frameworks for EL advanced within the field of EE (adapted from McBride et al., 2013)

Year	Author(s)/Organization	Description of framework
1978	Tbilisi Declaration, UNESCO	Five categories of objectives: (1) awareness, (2) knowledge, (3) attitudes, (4) skills and (5) action
1980	Hungerford et al.	Four goal levels for EL: Level I, ecological foundations; Level II, conceptual awareness; Level III, investigation and evaluation; Level IV, issue resolution
1990	Iozzi et al.	Five taxonomies of educational objectives for EL: cognitive domain, affective domain, responsible environmental behaviour, locus of control, assumption of personal responsibility
1991	Marcinkowski	Nine items comprising EL: (1) awareness and sensitivity; (2) attitude of respect and concern for the natural environment; (3) knowledge and understanding of how natural systems work; (4) understanding of the various environmentally related problems and issues; (5) skills required to analyse, synthesize and evaluate information about environmental problems; (6) sense of personal investment in and responsibility for the environment; (7) knowledge of strategies available for use in remediating environmental problems; (8) skills required to develop, implement and evaluate single strategies, and composite plans for remediating environmental problems; (9) active involvement at all levels in working towards the resolution of environmental problems.
1992	Roth	Three levels of EL: a nominally environmentally literate person can recognise and provide robust working definitions of many of the basic terms used in communicating for the environment and is developing awareness, sensitivity and an attitude and concern for natural systems. An environmentally literate individual has a broader understanding of the interactions between natural systems and human social systems. An environmentally literate person has moved beyond functional literacy in both the breadth and depth of his or her understandings and skills.
1994	Hungerford et al., EL Consortium	Four categories of objectives for EL: cognitive dimensions, affective dimensions, additional determinants of ERB, personal or group involvement in ERB
2000/2004	NAAEE	Four strands of EL: (1) questioning, analysing, and interpretation skills; (2) knowledge of environmental processes and systems; (3) skills for understanding and addressing environmental issues; (4) personal and civic responsibility.
2008	McBeth et al.	Four components of EL: (1) foundational ecological knowledge, (2) environmental affect, (3) cognitive skills, (4) behaviour
2011	Hollweg et al., 2011	Four components of EL: (1) contexts, (2) competencies, (3) environmental knowledge, (4) dispositions towards the environment

Note. Framework terminology reflects the authors' usage. Frameworks sorted chronologically order based on initial publication date to reflect progression within the field. Abbreviations: ***ERB****, environmentally responsible behaviours;* ***NAAEE****, North American Association for Environmental Education;* ***UNESCO****, United Nations Educational, Scientific and Cultural Organization.*

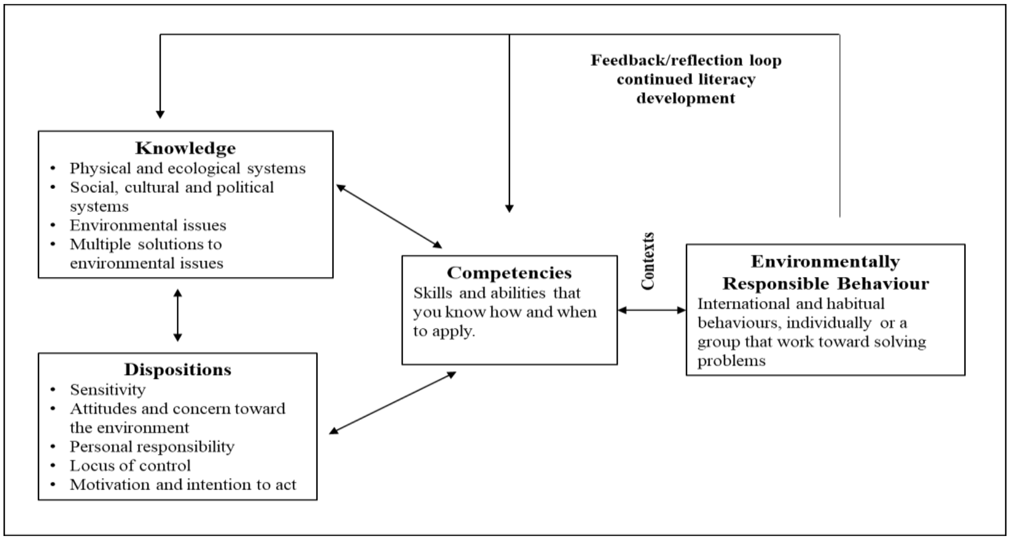

Figure 2.2 The domain of EL (adapted from Hollweg et al., 2011)

2.1.2.1 Components of environmental literacy assessment

According to the various historical frameworks of EL introduced in Table 2.2, the components of EL have always been challenged to better the status of EL. Evaluation studies are needed to determine the extent to which different EE programs and approaches have an appreciable effect on any of the various components of environmental literacy (e.g., McBeth et al., 2010; Stapp et al., 1978, 1979; UNESCO, 1978; Hollweg et al., 2011, pp. 1-4). Recently NAAEE has constructed four valuable domains: knowledge, cognitive and affective dispositions (attitudes), competencies (skills) and environmentally responsible behaviour (Table 2.3; Hollweg et al., 2011; Ireland, 2013; McBeth et al., 2008; Ramdas et al., 2014, pp. 382). The components of the knowledge domain include physical, ecological and environmental issues. Cognitive and affective dispositions contain sensitivity, attitudes and concern with the motivation and intention to act (Hollweg et al., 2011; Ramdas et al., 2014, pp. 382). Ecological knowledge is the ability to communicate and apply major ecological concepts such as energy production and transfer and the effects of social systems on natural systems (McBride, 2011; Williams, 2017, pp. 22-23). Knowledge of environmental issues is an individual's understanding of environmental problems and how politics influence them, educational, and economics. The cognitive and affective deposition considers an individual's sensitivity and attitude towards environmental issues such as pollution, technology, economics and conservation (Williams, 2017, pp. 22).

Table 2.3 Domains and components of EL (Ramdas et al., 2014, pp. 382)

Domains	Knowledge	Cognitive and affective dispositions
Components	• Physical and ecological foundations • Socio-political and cultural systems • Environmental issues • Alternative/multiple solution to environmental issues • Citizen participation and action strategies	• Sensitivity • Attitudes and concern • Personal responsibility • Locus of control/efficacy • Motivation and intention to act

Various tools used for measuring the component variables in EL and scales for EL have also been developed since the 1970s. (Danis, 2013, pp. 4). Before the 1990s, there had not been many attempts to measure EL. An early attempt was the revised ecology scale (Maloney et al., 1975), which was designed for adults and included verbal commitment, actual commitment, affect and knowledge scales. Later came the children's environmental attitude and knowledge scale (CHEAKS) developed by Leeming, Dwyer and Bracken (1995) for students in Grades 1 to 7, which included knowledge, attitude and behaviour scales; the environmental education literacy/needs assessment project (Marcinkowski & Rehrig, 1995) for high school students, which included knowledge, affect, skills and behaviour scales; and the middle school environmental literacy instrument (MSELI), developed by Bluhm, Hungerford, McBeth and Volk (1995), for students in Grades 6 to 8, which include knowledge, affect, skills and behaviour scales (Smith, 2014, pp. 144). Some of the assessment tools that were introduced above had impressive results, showing that ecological knowledge was higher than cognitive skills and finding low environmental sensitivity (Williams, 2017, pp. 26). There has also been growing interest in quantitative research measuring environmental attitudes, competences and beliefs in EE and ESD, and these assessment tools have been considered (Biasutti & Frate, 2017; Dunlap et al., 2000; Larson et al., 2011; Manoli et al., 2007).

2.1.3 Environmental literacy and science education

'Environmental Literacy', sometimes named as an *'Ecological Literacy'* was initially related and linked to ecological systems to elucidate environmental concern with a lack of scientific literacy in the 1980s (McBride et al., 2013, pp. 67). Williams has suggested that EL requires an

understanding of scientific principles related to ecology, the roles humans play in the ecosystem and the importance of environmentally responsible behaviours (Bruyere, 2008; Williams, 2017, pp. 22). Several studies, therefore, have focused the teaching about the environment to improve people's awareness about environmental responsibility in terms of conservation. Consequently, teaching must increase the awareness of people about the physical, biological, social, economic and cultural reactions to the environment (Karimzadegan et al., 2012, p. 404). Hungerford and Volk (1990) suggested that what is fundamentally necessary to be an environmentally responsible citizen is to have scientific knowledge of and be aware of the environment.

Where might this environmental curriculum be positioned: in geography, social studies, citizenship or science courses? Or is this the responsibility of EE courses (Pedretti, 2014, pp. 309). Subjects such as mathematics or science are firmly classified and framed. In other words, there is a clear boundary between the subjects and understandings of what is to be taught and learned. Other subjects such as EE, citizenship education and media studies are integrated, weakly classified and weakly framed. The boundaries between these subjects are unclear, and there is ambiguity about what should be taught and learned (Pedretti, 2014, pp. 309). EE has a cross-curricular theme without a clear subject status and may be stressed by the demands of fully knowledge-based and assessment-driven content such as that of science and other subjects (Littledyke, 1997, pp. 642). At this point, the interdisciplinary or multidisciplinary models related to EE should be focused on the pedagogical frames in schools.

Scientific literacy has been reflected in the discourse about EL. It was assumed that because the school-based science syllabus gives rise to the development of EL, it should also be explored for EE. (Karimzadegan & Meiboudia, 2012, pp. 406) outlined that SE has supported the talent and ability to obtain new scientific literacy and has helped humans to play better roles in their personal and social lives as citizens. EL aims to design a sustainable nature of living by creating new cognitive and social capacities and requiring the rise of an ecologically literate citizenry to understand global issues (Kaya et al., 2019, pp. 3; Smith, 2014, pp. 133). However, EL in science content, especially the teaching of environmental science, has not been fully cognizant of the social, political and economic dimensions of the natural world.

For this reason, environmental experts and educators have tried to address how those environmental issues should be explained in science curricula and textbooks that are meant to be used as educational tools to teach concepts related to the environment (Kaya et al., 2019, pp.

3). Thus, for SE, the design of efficient science curricula and textbooks is a major factor that contributes to the development of EL. This study will examine which science content in curricula are interrelated in the assessment of EL for secondary school students.

2.2 Environmental education in science curriculum at present

Environmental problems have often been seen as scientific problems that science and technology could solve, but increasingly even scientists have been arguing that science and technology are not enough to allow people to develop an understanding of environmental issues (Gough, 2011, pp. 2). Many researchers and educators have called attention to the status of EL among K-12 students and have come up with assessment projects to evaluate the status of EL (McBeth, 1997; McBeth & Bolk, 2010). The first assessments performed were focused on students' environmental knowledge and attitudes and have been done in many countries including the United States (McBeth, 1997; Wilke, 1995), Korea (Shin et al., 2005), Israel (Negev et al., 2008), Turkey (Erdogan, 2009) and Australia (Smith, 2014). The standard instruction of the science curriculum in school subjects has been discussed in order to understand EL in K-12. Lester et al. (2006) provided evidence that students with science knowledge could be more environmentally active than those without sufficient knowledge, and activism increased as they gained more knowledge. These evaluation studies show the difficulties in attempting to approach and develop better-designed EL programs in science curricula. In this study, we assessed Australian and Korean secondary students' EK and attitudes, which are components of international strands of EL.

2.2.1 Environmental education in the science curriculum in Australia

Australia has enforced the conservation of the natural environment and advocated for EE to help people stay at the forefront of education for sustainability. In general, Australian schools have made considerable progress in educating students about the environment and sustainable practices. The Australian science curriculum (NESA, 2018) emphasises sustainability using cross-curriculum learning to understand how environmental systems interact to support and maintain human life. EE programs in Australian schools are also underpinned by approaches to citizen science that involve students in collecting scientific data within their local environment, for example, collecting data about water or air quality, and biodiversity, which involves students in learning scientific information that directly affects their communities (Smith, 2014). In New South Wales (NSW) in 2001, the EE policy for schools aimed to support effective EE programs in government schools in the state. EE, however, is still not a major subject in school and struggles for acceptance in the mainstream curriculum in Australia, including guides for cross-curricular infusion in school-based EE, short courses in EE for teachers and educators, and improvement of systematic EE in the school curriculum (Tilbury et al., 2005).

2.2.2 Environmental education in the science curriculum in Korea

While Korea's previous education system had been more focused on delivering of standardised knowledge and rote learning there has recently been a new vision that seeks to promote flexibility and creativity in how the students address the new challenges of the 21st century (Cho, 2017). The Ministry of Education and Human Resources Development (MOE & HRD) has mentioned that future societies and industries will require people with creative problem-solving ability and has emphasized that the enhancement of creativity should be included in the goal of science education and suggested the necessity of revising in science curriculum in Korea (Choi & Paik, 2015).

EE began in the early 1980s in Korea with rapid economic growth, followed by a demand for pollution education due to the industrialisation of the 1960s (Lee & Kim., 2017). EE began to be carried out across a few separate related subjects, such as social science and science (especially biology) but became established as a separate elective subject called environmental science in the secondary school curriculum. The environment as a separate subject has been shown to help give students a basis for environment-related values and improve environmental knowledge (Lee, 2014). However, high-quality teacher training and related systems should be considered in order to upgrade the study of the environment and reduce the limitation that only students who have specially selected the environment as a subject can have the opportunity to learn highly informative environmental content. The Korean government has begun to support curricular and cross-curricular themes and has conducted various projects to support environmental education in schools (MOE, 2015). The 2015 Korean Revised Curriculum, based on case studies and critical competencies, now specifies a literature and science combined curriculum as an integrated curriculum in K-10 and more specified EE content in Years 11 and 12. Nowadays, an EE-based curriculum linking to STEAM education is emerging in Korean EE (Lee & Kim, 2017) in order to help develop students' environmental knowledge and attitudes as well as their environmental competencies and skills.

2.3 Environmental knowledge and attitudes in science education

As mentioned above, EK and EA are components of EL (Ramdas et al., 2014, pp. 379). These categories are essential in addressing environmental awareness and behaviour, respectively (Ajzen, 1985; Zsóka et al., 2013, pp. 127). At this point, does improving EK lead to more positive EA? This knowledge-attitude relationship has been studied by Arbuthnot and Lingg (1975), Oskamp et al. (1991) and Gamba and Oskamp (1994), who have suggested that EK is an important determining factor of EA (DeChano, 2006, pp. 16). Some studies proved that more knowledge about the environment leads to more positive attitudes towards the environment (Arcury, 1990; Bradley et al., 1999, pp. 17; DeChano, 2006, pp. 15).

In the school curriculum, EE is different from other disciplines, which require only curricular knowledge, due to consideration of behaviour towards environmental issues. It is rare to find any countries where EE is a compulsory subject like English and maths, and it is ordinarily carried out as an extra activity by outside environmental educators who visit schools and through community activities (Smith, 2010, pp. 7). Currently, EK tends to be taught as a co-subject in schools as a cross-curricular theme without a clear subject status (Kaya et al., 2019; Littledyke, 1997, pp. 642). It has also been reported that a lack of scientific knowledge in the understanding of nature and history of science may perpetuate a low value of environmental knowledge (Kaya et al., 2019). Further studies should be considered to examine the effect of scientific literacy in science school curricula to evaluate the level of EL from primary to tertiary school systems. The review below will examine the modern concepts of EK and EA and consider the measurement tools used to evaluate EK and EA to assess EL.

2.3.1 A measurement of environmental knowledge in science education

EK is a term used to mean knowledge and awareness of environmental problems and possible solutions to those problems (Zsóka et al., 2013, pp. 127). Providing EK is one of the external components in implementing EL in order to enhance students' awareness, attitudes, skills and behaviour towards the environment (Abdullah et al., 2011, pp. 1,025). The NAAEE has categorised three strands of EK: (1) ecological knowledge, (2) socio-political knowledge and (3) knowledge of environmental issues (Hollweg et al., 2011, pp. 2-3). Based on these categories, several countries have collected information about students' knowledge and attitudes towards environmental issues on a national scale (Ivy et al., 1998, pp. 182). These studies were conducted in the United States (Bohl, 1976; Perkes, 1973), Australia (Eyers, 1975), England (Richmond, 1976) and Israel (Blum, 1984). A survey questionnaire was used as a mean of collecting information about students' knowledge and attitudes about environmental issues (Ivy et al., 1998, pp. 182).

Science is one of the most relevant subjects for applying EK by approaching the mutual dependency relationship between scientific content and the environment. For example, the NSW science syllabus is called Science and Technology from early Kindergarten to Year 6, while the range of Year 7 to 10 are called Science (ACARA, 2010; Smith, 2014, pp. 47). In Year 11 to 12, the four traditional disciplines are categorized as biological, chemical, physical, and earth and space science, and a course entitled Earth and Environmental Science can be selected as an elective subject (Smith, 2014, pp. 45). However, the content is closer to geology and biology than the environment. In Malaysia, Science and Local Study is environmental content at the primary school level, and EE is integrated through science and geography at the secondary level. The Curriculum Development Centre has prepared an environmental education guidebook for teachers to implement EE across the curriculum of all subjects. However, the level of students' knowledge towards environment still appears to be lacking (Abdullah et al., 2011, p. 1025). Therefore, it is still necessary to evaluate the students' EK in term of the school context.

Various EK assessment questionnaire tests have been designed and developed to conduct relevant survey studies at various school levels. (Ivy et al., 1998; Hua, 1996; DeChano, 2006; Smith, 2014; William, 2017). In general, many researchers and environmental educators searched research papers and articles related to EL as a first step, selecting items that followed the research objectives that were guided by the definition of each element, then followed this with evaluation and validation from expert panels (Liang et al., 2018). However, one crucial thing found that there are rare to find environmental educators or researchers who consider school subject context to design the EK questionnaire. In our study, therefore, Bloom's taxonomy, a curriculum taxonomy analysis, was used to analyse Korean and Australian science syllabi and finalise the EK items. Bloom's Taxonomy and Revised Bloom's Taxonomy (RBT) are reviewed in terms of curriculum analysis below.

Bloom's taxonomy

Bloom's taxonomy (BT), originated by Benjamin Bloom and collaborators in the 1950s, is a set of hierarchical models used to classify education learning outcomes (Bloom et al., 1956). BT is a convenient way to help our students understand and use concepts and demonstrate particular skills and influence their values, attitudes and interests. This framework has been applied by teachers and college instructors in their teaching. There are six major categories in the cognitive domain: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom et al., 1956). Krathwohl (2002) stated that RBT, revised from original BT, has many merits in analysing learning objectives, can serve as a universal language about learning objectives, and provides teachers and educators with a standard frame of reference that clarifies various types of learning outcomes. RBT, therefore, may be a useful tool for analysing and assessing environmental science curricula in EE in order to evaluate the students' EL (Smith, 2014).

In the original version of BT, the cognitive domain was divided into the six categories listed above. BT was revised in 2001 (Amstrong, 2016; Anderson et al., 2001) and referred to as revised Bloom's taxonomy (RBT). The theoretical framework for the fundamentals of RBT outlines how to establish, organise and classify educational objectives for the cognitive domain (Anderson et al., 2001). In the original taxonomy, the categories embodied both a noun and verb aspects. Based on these two aspects, one dimension was revised to two dimensions: the knowledge dimension and the cognitive process dimension. The new knowledge dimension now contains four main categories: factual, conceptual, procedural and metacognitive. The cognitive process dimension contains six categories based on verbs: remember, understand, apply, analyse, evaluate and create. RBT has been used for all academic subjects and allows comparisons of standards from different subjects because teachers need a framework to help them make sense of objectives and organise them so that they are clearly understood and easy to implement (Anderson et al., 2001). In this study, RBT will be beneficial in analysing and assessing the validity of science content for EK in both Australian and Korean secondary science curricula.

2.3.2 A measurement of environmental attitudes in science education

EA is defined as a combination of personal experience, cultural norms and values that form opinions on environmental issues (Daudi, 2008) and consists in three dimensions: environmental worldview, concern and commitment (Ramdas et al., 2014, pp. 383). According to Ogunjinmi (2012), attitudes are favourable or unfavourable feelings towards a characteristic of the physical environment or a related problem and are therefore directly related to behavioural changes (Boiyo, 2014, pp. 19). EA are commonly perceived as preconditions for achieving environmental behaviour (Eilam et al., 2012, pp. 2,212).

Understanding students' EA has recently been a central goal of EE for education for sustainable development (Biasutti & Frate, 2017; La Trobe et al., 2000). It is necessary to investigate the attitudes that inform humans' relationships with their physical environments to understand how environmental problems recognised by individuals. Some researchers have investigated the effect of EA in science content, including school textbooks, school science programs and science syllabi (Karimzadegan & Meiboudia, 2012; Liang et al., 2018) and have found that only EK is highly focused on in science curricula and textbooks, with little attention given to attitudes and the positive relationship between EK and EA. Exploring how to upgrade EA in school subjects is necessary to establish a high level of EL in students of all ages. It is also necessary to develop an instrument to measure EA based on the scale of EK in science education.

There are some scales to measure EA in EE research areas, for example, the 2-factor model of environmental values (2-MEV) scale (Bogner & Wilhelm, 1996), Children's Attitudes toward the Environment Scale (CATES) (Musser & Malkus, 1994). In this study, we choose New Ecological Paradigm (NEP) due to that the scale has been widely used measure of people's shifting worldview from a dominant human view to an ecological view (Van Petegem & Blieck, 2006).

New Ecological Paradigm

At the beginning of the 1980s, research about environmental attitudes in children and young adults were concerned with perceptions of specific local environmental issues, such as energy use at home (Pallak et al., 1980), pollution and the misuse of natural resources (Iozzi, 1981). Traditional measures of 'environmental concern' have become supplanted by instruments seeking to measure 'ecological consciousness' (Ellis & Thompson, 2014), 'anthropocentrism' (Chandler et al., 1993) and 'anthropocentrism versus ecocentrism' (Thompson et al., 1994). Pirages and Ehrlich (1974) pointed out that the dominant social paradigm (DSP), described as 'the prominent worldview', had begun to be challenged by new beliefs and attitudes. The DSP aimed to exploit nature in order to improve people's quality of life (Reyna et al., 2018). In the 1970s, environmental issues such as water pollution and resource conservation were revealed to be significant problems and described as 'environmental concerns' (Dunlap et al., 2000; Weigel & Weigel, 1978). These environmental issues caused environmental awareness and beliefs to become prominent in school education, including the development of EE programs for the improvement of students' environmental attitudes. Weigel and Weigel (1978) developed the Environmental Concern Scale, 16 Likert-scale items assessing respondents' concerns about conservation and pollution issues and tested and endorsed its reliability and validity. Dunlap & Van Liere (1978) developed a new instrument called the 'New Environmental Paradigm' (sometimes called the original NEP) to challenge the DSP by rejecting the idea that nature has no value beyond its use for humans.

The 'new ecological paradigm' (NEP) scale, originally created and developed by Dunlap et al. (1978), has become the most widely used to measure of environmental concern in the world. The revised NEP scale for children allows for similar investigations of the development of children's environmental attitudes, how they change because of new experiences or educational programs, and how the EL of children from different socioeconomic or cultural backgrounds compare. Some studies have measured secondary school students' attitudes using NEP. No questionnaire is suitable for adolescents. Recently, a study by Harrison, Valine, Son and Chu (under review) restructured the dimensions of NEP for adolescents using NEP for children and NEP for adults.

The original NEP was composed of three dimensionalities: limits to growth, steady state, and balance of nature by rejecting anthropocentric notions. It had 12 items that appeared to represent a single scale based on how populations responded to them (Dunlap & Van Liere, 1978). It was, however, limited in that the scores depended on age, education and political ideology. Dunlap and colleagues then developed a revised NEP scale to respond to criticisms of the original NEP (Dunlap et al., 1984; Dunlap et al., 2000). The revised NEP has 15 items, with eight items that reflect the endorsement of the new paradigm and seven items that represent an endorsement of DSP. After that, the dimensionality of NEP was revised to adjust to participants ranging from adults to children (Harraway et al., 2012; Izadpanahi et al., 2018; Manoli et al., 2007). The revised NEP scale has been utilised in over 300 studies to measure environmental content, making it the most widely used measure of environmental concern by quite a margin (Danielle, 2015) and showing its usefulness for cross-cultural applicability. In this study, our group re-modified the revised NEP scale for adolescent students and the NEP scale for adolescences includes additional attitude questions related to the strands of international EL components.

2.4 Conceptual framework of the study

It is crucial to develop EE programs that are based on each country's own ecological, cultural, political, educational and economic context (UNESCO, 1980, 1985). Various EL frameworks have struggled to formulate these programs based on the principles, goals and objectives of UNESCO: knowledge, skills, attitudes and behaviour (Roth, 1992; Simmons, 1995; Wong et al., 2018, pp. 131). Furthermore, these frameworks addressed the natural world, environmental issues and environmental sustainability to solve these environmental issues (Wong et al., 2018, pp. 131).

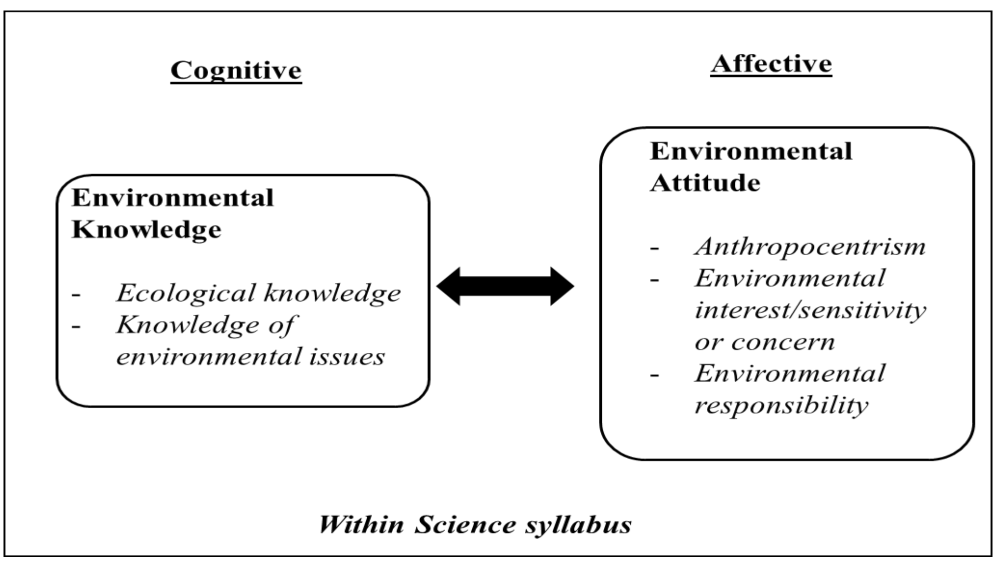

Figure 2.3 The conceptual framework of the relationship between EK and EA

This study explores the strength of the relationship between EK and EA, which are factors of strands of the international EL framework, in secondary school students, providing a comparative questionnaire survey analysis. The findings presented here are organised using the framework we developed from the hypothesis that a high score in knowledge about the environment during a school science program will proportionally affect positive affective outcomes such as attitudes and worldview about the environment. Figure 2.3 is a summary of the conceptual framework of this study. Recognising the importance of investigating cognitive and affective demands in science curricula educational goals, we thus attempt to analyse and compare the intended secondary science curriculum in Australia and Korea. ELTSQ survey test which has been designed and developed is hoped to be major instrument to extract the hypothesis of the framework. This new EL assessment test should be the preliminary step to lead to a high level of outcomes of students' EL.

CHAPTER 3: METHODOLOGY

3.1 Overview

This study aims to assess EK and EA in the secondary students in the science context. To imply this, new ‘Environmental Literacy Test for the Secondary School Questionnaire’ (ELTSQ) was constructed by collecting and modifying from the previous survey questions that have been used for the assessment of EL (e.g., DeChano, 2006; Smith, 2014; Wisconsin Center for Environmental Education, 1997; Williams, 2017) after implementation of RBT analysis in the secondary science context from two countries’ science curricula/syllabi. Validation processes were performed, followed by reliability, was also conducted. The correlation of the secondary students’ EK and EA was also analysed. This chapter includes research design, curriculum analysis method, participants and sampling method, data collection, validation process and data analysis.

3.2. Research design

Table 3.1 is a flow chart for the methodological process in this study. To design the ELTSQ, Australian (NSW) and Korean science curriculum analysis were conducted using RBT. The questions for EK were prepared based on the consequence of curriculum analysis and the questions for environmental attitudes were composed of *NEP*, which recently revised by our research team (Manoli et al., 2007; Harrison et al., under review) and *Disposition*, which derived from NAAEE strands (Simmons, 1995; Hollweg et al., 2011). The validation processes of the ELTSQ, including content validation, face validation, and semi- interviews with students, were carried out. The ELTSQ survey was implemented to Korean secondary students, data were collected and the reliability, frequency analysis, and correlation in each scale, sub-scales and item-categories in ELTSQ were analysed to investigate the item internal consistency across questionnaire.

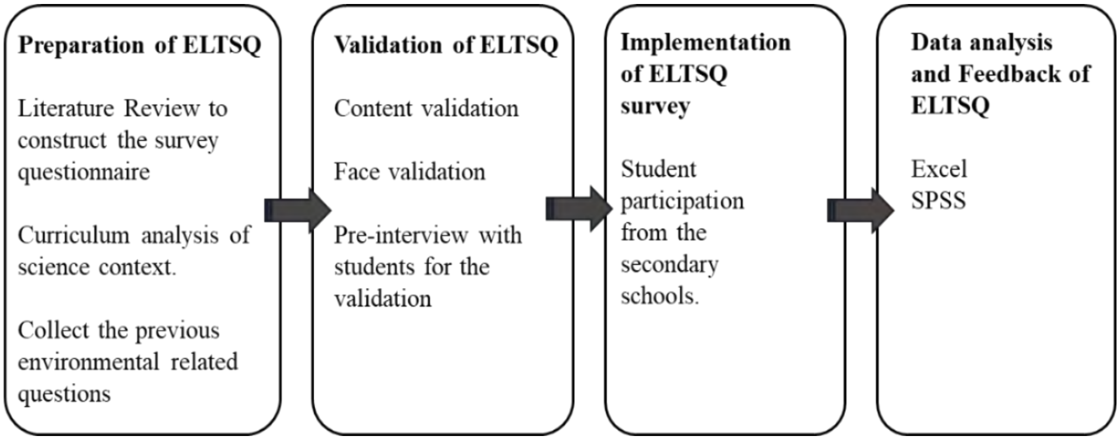

Figure 3.1 Overview of the procedures

3.3 Participants

The student participants involved in this study will be secondary school students. Approximately 400 Korean students from Years 7–10 participated in this study. Due to time limitations, Australian student data could not be included in this study. For this survey of the developed ELTSQ, secondary schools near Seoul in Korea were randomly selected from among schools where the principals had indicated their interest in this study. The research information and consent forms were sent to school principals. Teachers collected the students' and parents' consent forms, which recorded their agreement to participate in this survey. The ELTSQ was trailed at a time convenient to the schools involved. Semi-structured interview with four students was conducted and discussed under person to person with the inquiry-based interview protocol for approximately 30 min.

3.4 Curriculum analysis

To design the appropriate questionnaire of the ELTSQ for Australian and Korean secondary school students, the curriculum analysis was performed in science syllabus. EK related science contents were extracted based on their current curriculum board content outcomes from Year 7 to 10 science syllabi. (NESA, 2018; MOE, 2015). EE related contents outcomes were analysed using RBT based on the knowledge and cognitive process dimensions presented by Krathwohl (2002).

3.4.1 Environmental education-related content outcomes in secondary science syllabus

For Australia, content outcomes were selected from NSW science syllabus, which is the new K-10 Science Syllabus (NESA, 2018). The contents in NSW secondary science syllabus was structured for two stages, stage 4 (Years 7-8) and stage 5 (Years 9-10). In this study, *knowledge and understanding* strands, which composed of *Physical world (PW), Living World (LW), Earth and Space (ES)* and *Chemical world (CW)* were considered to select EE-related content outcomes for RBT analysis. Additionally, the contents with the symbol of Environmental Sustainability “ ” in science syllabus were included as EE contents outcomes.

For Korea, EE related contents were selected based on the 2015 revised national curriculum (MOE, 2015) of year 7 to year 10 secondary school science curriculum. The list of EE related content outcomes was extracted from the achievement standard in each grade science subject. The achievement standard explanation section was sometimes considered when the EE content outcome was a little elusive statement. The study did not consider the ‘*environmental’* subject in Korea which is an elective subject because only 221 (6.8 %) out of 3227 middle schools and 300 (12.8 %) out of 2342 high schools across the nation chose ‘Environment’ as a subject (MOD, 2016; Lee et al., 2017, pp. 11) and only 8.4% of schools in Korea select the Environmental elective subject in 2018 (Choi, 2019), that is so that the subject has been taught to the limited number of students in Korea. To translate Korean secondary science curriculum, Google Translate program was used to translate from Korean to English, followed by paraphrasing rephrased the wrong English expressions. This translation process conducted for face validation of coding among three science educators (one Korean speaking science educator and two English speaking science educator).

3.4.2 Methodological design for Revised Bloom’s Taxonomy

In this study, Revised Bloom’s analysis (RBT), which compensates for these shortcomings, consists of two-dimension systems, four knowledge dimensions and six cognitive process dimensions (Anderson et al., 2001) and has used for the analysis of educational objective and student learning. Table 3.1 shows the structure of a two-dimension system to analysis learning objectives.

Table 3.1 Revised Bloom's Taxonomy worksheet for cognitive process and knowledge dimension. (developed based on Anderson et al., 2001)

	RBT worksheet	Cognitive Dimension					
		Remember	Understand	Apply	Analyse	Evaluate	Create
Knowledge Dimension	Factual Knowledge						
	Conceptual Knowledge						
	Procedural Knowledge						
	Metacognitive Knowledge						

The RBT coding scheme uses the verb phrase and the noun phrase of a learning outcome to code for the cognitive process and knowledge dimensions, respectively. The cognitive process dimension consists of six categories which lie on a continuum of increasing cognitive complexity — *Remember, Understand, Apply, Analyse, Evaluate,* and *Create.* The knowledge dimension has four types of knowledge — *Factual, Conceptual, Procedural, and Metacognitive* (Anderson et al., 2001).

In this study, the coding process of EE content outcomes selected from the year 7 to 10 science curriculum was carried out by two independent researchers. When disagreements were made on the results of the analysis, the study proceeded in a manner of drawing consensus through discussion of the researchers. In order to secure the reliability of the researcher's analysis, Kappa value was calculated in NSW (Kappa = 0.92 in cognitive process and Kappa= 1 in Knowledge dimensions) and Korea (Kappa = 0.780 in cognitive process and Kappa = 0.9 in Knowledge dimensions), indicating all reliable agreements on RBT coding of the EE-relation contents.

In RBT coding scheme for the EE content outcomes in NSW science contexts, action verbs where are mentioned in learning/content outcomes were initially discussed their relevant categories of cognitive dimension based on many action verbs tabled by various universities and research groups (e.g. Anderson et al., 2001; Dalton & Smith, 1986). For example, 'explain' was considered to the category of *Understand*, because most (more than 90%) research groups decided and published to put this action verb in *Understand* of cognitive dimension. For the decision of knowledge dimension for EE related content outcomes, noun phrase of each content outcome was discussed by referring knowledge and understanding objective and statement and sometimes additional contents were optionally preferred to decide the category of knowledge dimension.

In the RBT analysis for EE content outcomes in the revised Korean science national curriculum, all action verbs were translated by Google Translate application and then rephrased by decision of two researchers to select a relevant action verb in English followed by considered to decide the category of this rephrased action verb under the same instruction that was applied in the decision of cognitive dimension of NSW science curriculum. When two or more verbs were identified in the content outcome, two or more categories were classified and analysed respectively (Choi et al., 2015, pp. 279).

For the consideration of knowledge dimension for EE content outcomes from Korean secondary science syllabus, the explanation of 'achievement standards' were preferred to consider the noun phrase, because achievement standards describe the content of the curriculum and the learners' ability to achieve it and, therefore, RBT analysis can help to identify which types of knowledge are emphasized and which thinking processes are being promoted (Kim et al., 1998; Choi et al., 2015, pp. 279).

Additionally, the topographical map was also produced following Porter's aliment measure (Porter, 2006). The representations have been widely used for curriculum research (Liu et al., 2009; Lee et al., 2015). To make the two tables comparable, all cell values are converted into ratios totalling to 1. The porter alignment index (p) is defined as follows:

$$P = 1 - \frac{\sum_{i=1}^{n} |(X_i - Y_i)|}{2}$$

Where *n* is the total number of cells in the table and *i* refers to a specific table cell, ranging from 1 to *n*. For example, with knowledge dimension, this is 3 x 4 tables, there are 12 cells, thus n=12. Xi refers to the ith cell of Table X (e.g., NSW knowledge dimension) and Yi refers to the corresponding cell (ith cell) in Table Y (e.g., Korea knowledge dimension). Both Xi and Yi are ratios with a value from0 to 1. The sum of $X1$ to Xn is equal to 1, so is the sum of $Y1$ to Yn. The discrepancy between the ith cells of the test table and the standard table can be calculated as $Xi - Yi$. The total absolute discrepancy is then calculated by summing the absolute discrepancies over all cells.

3.5 Environmental literacy assessment in secondary science

In this study, the ELTSQ consisted of two scales, the Environmental Knowledge (EK) and Environmental Attitudes (EA). The items in the EK scale in the ELTSQ divided into two sets based on the school Years. For students in Years 7-8, 37 questions were selected, and for students in Years 9-10, 50 questions were selected based on content analysis in science curriculum/syllabus.

Table 3.2. The questionnaire structure of the ELTSQ

Scales and subscales	Definition
Ecological knowledge#	
(1) Natural resources	Relevant ecological and earth system in nature (e.g. **ECNR1**. Which of these materials are made from renewable natural resources?)
(2) Energy	Scientific understanding and technological development about renewable energy, energy transfers contributed to finding solutions to energy-related problems. (e.g. **ECE1.** What form of energy is released from coal when it is burnt?)
(3) Biodiversity (Ecosystem)	Human and variable in ecosystems and earth system. (e.g. **ECB1.** Ecology is the study of the relationship between:)
Knowledge of environmental issues**	
(1) Environmental issues	Arise from human conflicts about environmental problems and solutions, including the causes and effects of those conflicts. (e.g. **EI1.** What is an increase in the average global surface temperature called?)
(2) Environmental sustainability	Citizen participation and action strategies to solve environmental problems. (e.g. **ES1.** Approximately 70% of all fresh water withdrawn for human use is used for:)
NEP*	
(1) Rights of nature	Nature in all its life forms has the right to exist, persist, maintain and regenerate its vital cycles (e.g. **NRN1*** Humans have the right to rule over nature.)
(2) Eco-crisis	Human intervention in nature may lead to negative results at a disastrous level. (e.g. **NEC1** If things continue the way they are now, we will have a big environmental disaster.)
(3) Human exemptionalism	The belief that humans are exempt from the constraint of nature (e.g. **NEH1** Human's problem-solving abilities will ensure that we can avoid ruining the earth.)
Disposition**	
(1) Environmental sensitivity	The expression of caring and positive feelings toward the environment. (e.g. **DES1** People should give importance to the environment)
(2) Environmental concern	Attitude that pertain to environmental problems under the general environmental concern (e.g. **NEC1** If things continue the way they are now, we will have a big environmental disaster.)
(3) Environmental responsibility	Personal commitment to environmentally corrective behaviour. (e.g. **DER1** I can help the people working for the solution of environmental problem)

*# NESA (2018) * Dunlap et al., 1978; Dunlap et al., 2000, ** Hollweg et al., 2011*

The knowledge scale consists of two sub-scales: *ecological knowledge* (ECK) decided to 3 item categories: natural resources (ECNR), energy (ECE), biodiversity (ecosystem) (ECB) and *knowledge of environmental issues* (KEI) decided to have two item categories: environmental issues and environmental sustainability. The attitudes scale consists of *NEP* which includes three subscales: rights of nature, eco-crisis, and human exemptionalism (Harrison et al., under review) and *Disposition* which was categorised from NAAEE (Hollweg et al., 2011). The types of item categories are environmental sensitivity, environmental concern, and environmental responsibility (Table 3.2).

3.5.1 Design of environmental knowledge questionnaire

They are all multiple-choice questions with only one correct answer, and they incorporate the issue areas compiled in the ecological system in nature and the global and local environmental issues according to the content that was identified from science curriculum/syllabus analysis using RBT. The knowledge questionnaire was planned to be implemented to both NSW and Korean secondary students in accordance with their age, gender, culture, and environmental program experience. However, in this study, we implemented the questionnaire to only Korean students. Australian students' responses will be collected in 2020 for further studies. The list of questions is provided in Appendix I.

The one of subscales in EK, Ecological Knowledge (ECK), includes 5 questions of natural resources item category, containing the types of natural resources, how natural resources are related Earth's spheres, and development of new materials, 8 questions of energy item category involved in the renewable & non-renewable, understanding of energy production and transformation, and development of new energy for energy conservation, and *12 questions of* biodiversity (ecosystem) item category, related to the story of food chain and food web, adaptation, and sustainable ecosystem (NESA, 2018; MOE, 2015). The list of questions on the EK scale was provided in Table 3.3.

In the construct of the other subscale in EK, *knowledge of the environmental issue (KEI)*, there are two item categories: environmental issues (EI) and Environmental Sustainability (ES). For environmental issues and problem category, 15 questions are closely related to *the Global issue on environments such as global warming*, climate change, greenhouse effect. In environmental sustainability subscription, 10 questions are related to Human and environment

(Human's effort) and Environmental protection system for the sustainable environment (NESA, 2018; MOE, 2015). The list of EK questions was summarised in Table 3.4.

Table 3.3 List of question items in ecological knowledge subscale

Ecological Knowledge (number of items)	Questions
Natural resources (5 items)	**ECNR1**. Which of these materials are made from renewable natural resources? **ECNR2.** Why are the fossil fuels coal, oil and gas known as non-renewable resources? **ECNR3.** What is the water cycle? **ECNR4.** Which of these gases is NOT a greenhouse gas? **ECNR5.** Most people know that hybrids use electricity to achieve good gas mileage and have emerged as a bridge between the benefits and limitations of both electric and gasoline powertrains. The hybrid is an innovative system for the environment because it produces:
Energy (8 items)	**ECE1.** What form of energy is released from coal when it is burnt? **ECE2.** Which of the statements on energy transformation below is not correct? **ECE3.** The original source of energy for almost all living thing is: **ECE4.** Which of the following is NOT renewable energy? **ECE5.** Solar panels on a house roof convert: **ECE6.** Hydroelectric energy is energy derived from the movement of water. The energy is produced by: **ECE7.** Which type of energy will be available for human use for the longest period of time? **ECE8-H*.** Which of the following is most likely to be an important worldwide source of energy for the future?
Biodiversity (ecosystem) <u>(5 items)</u>	**ECB1.** Ecology is the study of the relationship between: **ECB2.** Which of the following is a producer in an ecosystem? **ECB3.** There are many kinds of animals and plants, and they live in many different types of environments. What word is used to describe this idea? **ECB4.** Most of the oxygen in the atmosphere comes from: **ECB5**. Some people started a program in a national forest to protect deer. They started killing wolves. Ten years later, there were no wolves in the forest. For a few years after the wolves were gone, there were many more deer than there had ever been. Then suddenly there were almost no deer. The people who wanted to protect the deer didn't know that: **ECB6.** What happens immediately in an ecosystem if a producer cannot use the energy from the sun? **ECB7.** If there were no decomposers on Earth, what would happen? **ECB8-H*.** Features that help an animal survive are called: **ECB9-H*.** When two or more species attempt to use the same limited resource in an ecosystem, their interaction is called: **ECB10-H*.** Biotic components are the living things that shape an ecosystem. which of the following is a biotic feature? **ECB11-H*.** A pollutant gets into an ecosystem and harms insects. How might this affect the ecosystem? **ECB12-H*.** After living things die, they decompose. As a result of this process, nutrients are:

*The question with * means that the question was used for only Years 9-10 students' survey questionnaire.*

Table3.4 List of question items in the knowledge of environmental issues subscale

Knowledge of Environmental issues	Questions
Environmental issues and problems (14 items)	**EI1.** What is an increase in the average global surface temperature called? **EI2.** The burning of fossil fuels has increased the carbon dioxide content of the atmosphere. What is the most immediate effect that this increasing amount of carbon dioxide is likely to have on our planet? **EI3.** Waste thrown into bodies of water kills fish because of the decaying waste: **EI4.** Which of the following is the cause of the 'greenhouse effect'? **EI5**. Which of these is a likely consequence of climate change? **EI6.** Which action can have the greatest impact on reducing the threat of global warming? **EI7.** Many people believe that the Earth's average temperature is changing. They say that one **EI8.** Acid rain is a problem because: **EI9.** Which of the following would be most likely to cause soil pollution? **EI10.** Deforestation is the conversion of forested areas to non-forest land for human use. What is deforestation responsible for? **EI11-H*.** The layer of ozone in the Earth's atmosphere has developed holes because: **EI12-H*.** Why do people continue using energy sources that cannot be quickly replaced? **EI13-H*.** Carbon dioxide, methane, water vapour and nitrous oxide are examples of what? **EI14-H*.** **El Niño** events are associated with a warming of the central and eastern tropical Pacific, while **La Niña** events are the reverse, with a sustained cooling of these same areas. Which of the following statements is not correct?
Environmental sustainability (11items)	**ES1.** Approximately 70% of all fresh water withdrawn for human use is used for: **ES2.** In the distillation of saltwater into fresh water, heat is used to: **ES3.** Conservation is a term used often when discussing the environment. We need to conserve energy. We need to conserve water. What does the word 'conserve' mean when used in this way? **ES4.** One energy source for humans is nuclear energy. However, people disagree with: **ES5.** The primary environmental benefit of a wetland is: **ES6.** The pollution of ocean water is a serious problem because: **ES7.** How should humans best relate to nature? **ES8.** Hydroelectric power is beneficial to the environment because it uses the natural flow of water to turn large: **ES9-H*.** One suggested advantage of using nuclear power plants instead of coal or oil for energy production is: **ES10-H*.** Sustainable agriculture aims to: **ES11-H*.** Extensive planting of trees to increase forest cover is called:

*The question with * means that the question was used for only Years 9-10 students' survey questionnaire.*

3.5.2 Design of environmental attitude questionnaire

The participants' responses to the EA questions were coded with their strength of agreement by using a Likert-type scale (Likert, 1932) with the statements from *strongly disagree* (score, 1) to *strongly agree* (score, 6). The classification map of the EA is summarised in Table 3.5.

Table 3.5 The items map of Environmental Attitude for secondary school students

	Category	Question
NEP	Right of nature	**NRN1*** Humans have the right to rule over nature.
		NRN2 Living things in nature have the same right as humans to live.
		NRN3 Even though our technology is advanced, humans are still under the laws of nature.
		NRN4 The earth has plenty of natural resources for humans.
		NRN5 The earth has a limited supply of room and resources.
	Eco-Crisis	**NEC1** If things continue the way they are now, we will have a big environmental disaster.
		NEC2 The earth can support only a limited number of people.
		NEC3 Humans are really messing up the environment.
		NEC4 When human change things in nature, it usually causes serious problems.
		NEC5 Nature is easily pushed off balance.
	Human exemptionalism	**NEH1** Human's problem-solving abilities will ensure that we can avoid ruining the earth.
		NEH2 Nature is strong enough to handle our modern lifestyle.
		NEH3 Humans will someday know enough about how nature works to be able to control it.
		NEH4 The "environmental crisis" that many people talk about is not really a big problem.
		NEH5 When humans need things, we have the right to make changes to the natural environment.
		NEH6 To make the environment healthier, humans need to change their actions.
Disposition	Environmental sensitivity	**DES1** People should give importance to the environment
		DES2 I believe that I am sensitive to the environment
		DES3 I want to encourage people to do something so as to protect the environment.
		DES4* I am not interested in the beauty of nature around me such as flowers, trees, or clouds
	Environmental concern	**DEC1** Predacious and wild animals such as snakes should not be killed because they also have the right to live.
		DEC2 I get angry when I think about some companies using animals for experiments
		DEC3* I do not concern about the light on in the empty classroom in school because the school pays for the electricity bill.
		DEC4* Global warming is largely a scare tactic by environmentalists.
	Environmental responsibility	**DER1** I can help the people working for the solution of environmental problem
		DER2 I can change my lifestyle to protect natural resources.
		DER3 I would be willing to donate my allowance of $20 to an animal protection agency for endangered animals such as wolves and bears.
		DER4* The conservation of natural resources is totally the government's responsibility.

**: Deleted items after Cronbach alpha reliability calculations.*

In the revised *NEP* in the EA scale, there are item categories: right of nature, eco-crisis, and Human exemptionalism which are adapted from the NEP revised by Manoli who researched for the assessment of children's environmental attitudes (Manoli et al., 2007). Right of nature (NRN1-5) is adopted from Anti-anthropocentrism that is the belief of humans, could change and control the environment (Dunlap et al., 2000). Eco-crisis (NEC1-5) is mainly adapted from Dunlap's scale of NEP responsible for Eco-Crisis that is the belief that humans cause environmental damage. Human exceptionalism is adapted from Anti-exceptionalism, the belief that human was responsible for preserving nature (Manoli et al., 2007; Dunlap et al., 2000).

Disposition was also categorised in the EA section based on Simmons's framework and strands who related to the NAAEE (Simmons, 1995; Hollweg et al., 2011). According to the NAAEE strands, environmental sensitivity (DES1-4) (Chawla, 1998; Sward & Marcinkowski, 2011; Hollweg et al., 1,022, pp.2-4), environmental concern (DEC1-4) (Van Liere & Dunlap, 1980; Hollweg et al., 1,022, pp.2-4) and environmental responsibility (DER1-4) (Bandura, 1977; Hollweg et al., 1,022, pp.2-4) were focused to characterise how secondary school respond to environmental issues under the concept of cognitive and affective dispositions.

3.5.3 Validation process of the ELTSTQ

To finalise items in ELTSQ, the validity of various validity methods was followed. Firstly, the content validation of ELTSQ conducted by two experts in SE and one expert in EE. The experts read and discussed regarding the value of knowledge questions either these questions are adjusted to each grade to prove that the students were educated this items or area through the science curriculum. The four-agreement Likert scale was organised to make the experts easily decide either the question is suitable to assess EL in scale, subscale and item categories.

The collected data was analysed using the Individual Content Validity Index (CVI) system (Lynn, 1986, Lee et al., 2016, p34). The experts' responses in the Likert scale were grouped with 1 and 2 as not relevant items (score 0) and 3 and 4 as relevant items (score 1). Second, face validation was also performed by three experts. One of the experts provides verbal comments on item wording for lower secondary school students. One of the experts met via online conference with research team members and expressed their thoughts on item fit in each scales, subscales and item categories. Their thought was summarized in the field note and referred it when we had to decide item deletion after reliability calculations. Lastly, students' semi-structured interviews were conducted to ensure participants could comprehend the questionnaire items and their responses were connected to what the items tried to measure. For these interviews, three interview questions were lined up in the ELTSQ questionnaire and an inquiry-based conversation with four Korean students constructed (two from Year 9 and two from Year 10), lasting 30 minutes each and conducted via the communication application 'Kakao Talk'. The interview questions were validated via assessment by professional educators. For example, what students thought of the environmental crisis and their explanations of why they thought it was a big issue/not a big issue. Students' interviews were recorded, and later the main points were summarised.

3.5.4 Data collection

The ELTSQ has two versions, a pen and paper version and an online version. Depending on the school's preference, we delivered a pen and paper version or online version questionnaire. The information and consent forms were given to the schools before the distribution of ELTSQ. Total of 379 students participated in this study (Years 7-8: 146 students, Years 9-10: 233 students). The participation from NSW secondary schools was not able to be achieved for this study. There will be follow up study in 2020, including data from NSW schools.

3.5.5 Reliability

The reliability of the ELTSQ was measured to investigate the internal consistency or stability using the Cronbach alpha reliability test. Alpha values greater than 0.7 in science education survey instruments are considered to indicate relatively high internal consistency (Taber, 2018). Items were deleted when the reliability of each item categories very low (below 0.5). We also referred to outcomes from experts' content validation and face to face validation.

3.5.6 Data analysis

For ELTSQ data analysis, the mean percentage of students correct/positive responses in each subscale and item categories were calculated to investigate students' environmental literacy, knowledge and attitudes. Independent *t*-test was conducted to identify the influence of different school years on students' environmental literacy. To make investigate how the scales, sub-scales and items categories relate to each other, the Pearson correlation coefficient was calculated. Correlation coefficient values ranging from 0.10 to 0.29 is regarded as weak correlation. Correlation coefficient values from 0.30 to 0.49 can be confirmed as moderate and more than 0.50 is a strong correlation. Additionally, positive correlation coefficients show that scales are positively associated, and negative correlation coefficients show that scales are negatively associated (Samuels, 2014). IBM SPSS statistics version 24 were used for statistical data analysis in this study.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter includes a curriculum analysis of the EE-related content outcomes for using RBT, validity and reliability of ELTSQ, and assessment and evaluation of students' EK and EA from the ELTSQ survey.

4.1 Curriculum analysis for environmental literacy in a secondary science context

In this study, curriculum analysis has performed a part of the content validation process for the designed questionnaire, especially the EK section. Initially, EE-related content outcomes were selected from the New South Wales (NSW) science syllabus for stage 4 and 5 and the Korean science syllabus for years 7-9 and the integrated science syllabus for year 10, respectively. In order to code these content outcomes, RBT was chosen as a useful method to examine the intellectual demands of the intended secondary science curriculum in Australia and Korea (Lee et al., 2015, pp. 2197).

4.1.1 Environmental-related content outcomes between Australia and Korea

In the NSW science curriculum, 26 (19.4 %) out of 134 content outcomes at stage 4 and 13 (10.7 %) out of 122 content outcomes at stage 5 science were selected as an EE content outcome. In the Korean secondary science curriculum, 6 (6.4 %) content outcomes from 94 middle school science (Years 7-9) and 12 (35.3 %) content outcome from 34 integrated science (Year 10) content outcomes were selected as an EE- related contents. The reason the small number of EE-related content outcomes in the Korean science curriculum may be the independent environmental subjects in the Korean education system.

Based on the selected EE content outcomes, four main environment-related learning areas were structured in both the NSW education curriculum board and the Korean National education curriculum secondary science subjects in Years 7 - 10 secondary science subject (MOE, 2015). Table 4.1 shows that 'Biodiversity (ecosystem)' category had the highest number of EE content outcomes in Years 7-10 of the NSW science curriculum, while 'Energy' category had the highest number of EE content outcome in the Years 7-10 of the Korean science curriculum. Interestingly, the 'pollution'-related contents, which is one of the main environmental issues, was rarely mentioned in the secondary stage. In the Korean education curriculum, this 'pollution' related content outcomes were listed in Year 5 and 6 (MOE, 2015).

Table 4.1 Recognition of EE related knowledge statements in Australian and Korean secondary science curriculum

Country	EE content areas	Number of content outcomes	Percentage
Australia	Natural resources	8	20.5
	Energy	7	17.9
	Biodiversity (ecosystem)	16	41.0
	Environmental issues and sustainability	8	20.5
	Total	**39**	**100.0**
Korea	Natural resources	2	11.1
	Energy	8	44.4
	Biodiversity (ecosystem)	5	27.8
	Environmental issues and sustainability	3	16.7
	Total	**18**	**100.0**

4.1.2 RBT Coding of Environmental Education Related Contents in Secondary Science Syllabus

In this study, the EE-related content outcomes from both countries' secondary science curriculum were classified and coded according to the two dimensions in RBT which is a two-dimensional category to map cognitive process as an action verb form and knowledge process as a noun form (Krathwohl, 2002).

4.1.2.1 RBT Coding in NSW Secondary Science Syllabus

Before the RBT analysis was conducted to code the EE-related content outcomes from the NSW secondary science curriculum, it is necessary what types of action verb have used in the science curriculum because one part of RBT analysis, cognitive process dimension, consider the type of action verb. Table 4.2 shows the frequency of action verbs in the cognitive dimension of EE-related content outcomes. 'Describe' (20.5 %) was the most popular action verb and 'Explain' (10.3 %) and 'Outline' (10.3 %) were also frequently used in EE -elated content outcomes. In accordance with action verbs for RBT coding, 'Describe' belongs to the *Understand* category in the cognitive process dimension. 'Explain' is also classified in *Understand* category and 'Outline' is an action verb in the *Remember* category in the cognitive process dimension.

Another interesting point was that there was no action verb which is related in the *Create* category, such as ‘Design’ or ‘Create’, in EE-related content outcomes from years 7-10 science curriculum.

Table 4.2 The frequency of action verbs in the cognitive dimension in NSW secondary science subjects. (within EE- related content outcomes)

Action verb	Frequency	Percentage
Analyse	2	5.1
Assess	1	2.6
Classify	1	2.6
Compare	1	2.6
Construct	1	2.6
Demonstrate	2	5.1
Describe	8	20.5
Discuss	3	7.7
Evaluate	3	7.7
Explain	4	10.3
Identify	1	2.6
Investigate	3	7.7
Outline	4	10.3
Predict	1	2.6
Recall	1	2.6
Recount	1	2.6
Relate	1	2.6
Research	1	2.6
total	**39**	**100.0**

Table 4.3 and Figure 4.1 show the profile of the EE-related content outcomes from NSW science curriculum classified according to RBT. We coded each content outcome along with two dimensions that include six categories in the cognitive process dimension and four categories in the knowledge dimension. According to the classification result in the cognitive dimension (Table 4.3), the *Understand* category had the highest percentage (51.3 %) of occurrences compared with the other factors, including *Remember*, *Apply*, *Evaluate* categories. The interesting thing that there was no *Create* category was according to the RBT analysis. In the knowledge dimension in the RBT coding process, the majority of EE-related content outcomes (82.0 %) were coded as *Conceptual* category with very few in the *factual, procedural* and *metacognitive* categories. The *Understand* category in RBT, which was known as *Comprehension* in original BT has been acknowledged as ‘probably the largest class of intellectual abilities and skills emphasised in schools and colleges’ (Bloom et al., 1956, pp.89;

Lee et al., 2015, pp. 2,201). EE-related content outcomes in the NSW secondary science curriculum were mostly correlated to *Conceptual* with *Understand*, indicating be focused on and limited to the basic knowledge about the environment and its issues without approaching the development of students' creative thinking about the environments on nature. Lee et al. (2015) emphasised that learners are expected to devise novel or different ways or tools by adapting scientific knowledge, which is often challenging tasks in the category of *Create*. More in-depth research is needed on how EE in the science syllabus can realistically develop students' EL.

Table 4.3 Classification of EE-related content outcomes (n=39) in the NSW secondary science syllabus (Years 7-10) according to the dimension of knowledge and cognitive processes in RBT

Cognitive / *Knowledge*	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**	**Number of knowledge items**
Factual	2 (5.1)	-	-	-	-	-	**2 (5.1)**
Conceptual	4 (10.3)	20 (51.3)	3 (7.7)	2 (5.1)	3 (7.7)	-	**32 (82.0)**
Procedural	-	-	2 (5.1)	-	-	-	**2 (5.1)**
Metacognitive	-	-	1 (2.6)	1 (2.6)	1 (2.6)	-	**3 (7.7)**
Number of cognitive items	**6 (15.4)**	**20 (51.3)**	**6 (15.4)**	**3 (7.7)**	**4 (10.3)**	**-**	**39 (100.0)**

Percentages shown in round brackets (%)

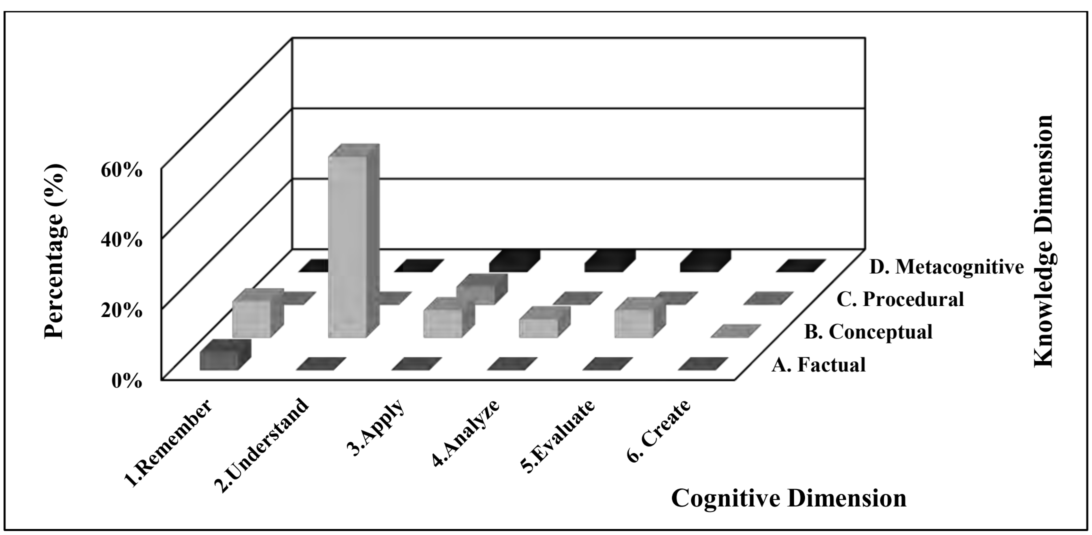

Figure 4.1 The classification of EE-related content outcomes (n=39) in the NSW secondary science syllabus (Years 7-10) according to the dimension of knowledge and cognitive processes in RBT

Table 4.4 shows that the highest number of EE-related content outcomes were from earth and space in Stage 4 (53.9 %) and the living world section in Stage 5 (61.5 %). The main EE-related contents in earth and space in Stage 4 is about Earth's resources and spheres, especially hydrosphere, as *"identify that water is an important resource that cycles through the environment."*. NESA, 2018 asserted that students should describe the dynamic nature of models, theories and laws in order to develop a scientific understanding of the Earth. They describe how advances in scientific understanding affect people's choices of resource use and management practices in shaping sustainable futures (NESA, 2018, pp. 21). In the living world section in Stage 5, ecosystem and biodiversity were the main EE-related content outcomes aimed at analysing the interaction between components and processes within biological systems. In Stage 5 students process, analyse and evaluate data and information from first-hand investigations to make conclusions based on the evidence, identifying sources of uncertainty and possible alternative explanations for findings (NESA, 2018, pp.21).

Table 4.4 EE-related content in knowledge and understanding of science in Stage 4 & 5 of the NSW science curriculum

Stage	Knowledge and understanding	Number of EE-related content outcome	Percentage
4	Physical world	1	3.8
	Living world	8	30.8
	Earth and science	14	53.8
	Chemical world	3	11.5
	Total	26	100.0
Stage	**Knowledge and understanding**	**Number of EE-related content outcome**	**Percentage**
5	Physical world	2	15.4
	Living world	8	61.5
	Earth and science	1	7.7
	Chemical world	2	15.4
	Total	13	100.0

In Tables 4.5 and 4.6, most of the scientific fields are distributed in the *Understand/Conceptual* category in RBT. Earth and space in Stage 4 and Living World in Stage 5 were distributed in various categories in the cognitive process dimension excepting of *Analyse* and *Create*. Many experiments in the case of Living world section require long-term observation, which appears to be due to the process of planning, observing and interpreting the results (Wee et al., 2011, pp.15). The EE related content outcomes in the Living World field, therefore, require a high level of cognitive process dimension like *Evaluate* category in Stage 5. In the case of the knowledge dimension in RBT, all four domains have more content outcomes related to *conceptual* knowledge than others. These outcomes suggest that EE-related content outcomes are based on forming concepts rather than acquiring skills, such as experimental procedures or how to use tools in NSW science subjects during Stages 4 and 5.

Table 4.5 Cognitive process dimension in RBT in knowledge and understanding in stages 4 & 5

Stage	Knowledge and understanding	Remember	Understand	Apply	Analyse	Evaluate	Create
4	Physical world	-	-	1 (3.9)	-	-	-
	Living world	-	7 (26.9)	1 (3.9)	-	-	-
	Earth and space	3 (11.5)	7 (26.9)	3 (11.5)	1 (3.9)	-	-
	Chemical world	-	2 (7.7)	1 (3.9)	-	-	
	Total (n = 26)	**3 (11.5)**	**16 (61.5)**	**6 (23.1)**	**1 (3.9)**	**-**	**-**
5	Physical world	-	2 (15.4)	-	-	-	-
	Living world	3 (23.1)	2 (15.4)	1 (7.7)	-	3 (23.1)	-
	Earth and space	-	-	-	-	1 (7.7)	-
	Chemical world	-	-	-	1 (7.7)	1 (7.7)	-
	Total (n = 13)	**3 (23.1)**	**4 (30.8)**	**1 (7.7)**	**1 (7.7)**	**5 (38.5)**	**-**

Percentages shown in round brackets (%)

Table 4.6 Knowledge dimensions in RBT in knowledge and understanding in Stage 4 & 5

Stage	Knowledge and understanding	Factual	Conceptual	Procedural	Metacognitive
4	Physical world	-	-	1 (3.9)	-
	Living world	-	7 (26.9)	1 (3.9)	-
	Earth and Space	2 (7.7)	11 (42.3)	-	1 (3.9)
	Chemical world	-	3 (11.5)	-	-
	Total (n = 26)	**2** (7.7)	**21 (80.8)**	**2** (7.7)	**1** (3.9)
5	Physical world	-	2 (15.4)	-	0
	Living world	-	7 (53.9)	-	1 (7.7)
	Earth and science	-	1 (7.7)	-	-
	Chemical world	-	1 (7.7)	-	1 (7.7)
	Total (n = 13)	**-**	**11 (84.6)**	**-**	**2** (15.4)

Percentages shown in round brackets (%)

4.1.2.2 RBT Coding in Korea Secondary Science Syllabus

Unlike EE related content outcomes in the NSW science syllabus, there were some EE-related content outcomes that were structured with two verbs in a sentence in the Korean science syllabus. If two verbs that were considered to code a cognitive process in RBT were both are action verbs, the content outcome was divided into two independent sentences and coded, separately. If one verb was an action verb, and the other verb was a non-action verb, such as 'know' or 'understand' in one EE content outcome, only the action verb was considered in coding the cognitive processes. Table 4.7 shows the frequency of action verbs in the cognitive process dimension of EE content outcomes in Korean science syllabus. The frequency of action verbs was less various compared to the frequency of action verbs in the Australian science curriculum. 'Discuss' (26.3 %) was the most popular action verb within EE content outcomes in the Korean science syllabus. The curriculum is robust in supporting teachers to develop learning experiences by clearly describing a range of content that embeds high order learning outcomes (Hattie, 2005; Lowe et al., 2013, pp.7). In Korean national curriculum, since environmental textbooks are distributed from primary school to secondary school, knowledge and understanding areas are mainly dealt with in environmental subjects, and EE-related content outcomes in Korean science subjects may tend to be more biased toward analysis and evaluation.

Table 4.7 The frequency of action verbs in the cognitive process dimension in Korean secondary science subjects (EE-related content outcome)

Action verb	Frequency	Percentage
Analyse	2	10.5
Discuss	5	26.3
Evaluate	1	5.3
Example	1	5.3
Explain	3	15.8
Illustrate	1	5.3
Infer	2	10.5
Investigate	2	10.5
Recognize	1	5.3
Research	1	5.3
Total	**19**	**100.0**

Table 4.8 and Figure 4.2 show the profile of the EE content outcomes from the Korean science curriculum classified according to in RBT. In the cognitive process dimension, *Understand* category was the highest percentage (38.9 %) compared with the other factors, including *Remember*, *Apply*, and *Evaluate* categories. No *Remember* and *Create* categories were coded. In the knowledge dimension, *Conceptual* category had a higher percentage (55.6 %) than *Procedural* and *Metacognitive* categories. EE content outcomes in the Korean secondary

science curriculum were also mostly correlated with the categories of *Conceptual* with *Understand*. The categories of *Conceptual* with *Apply* had a slightly higher correlation than the *Procedural* with *Apply,* which is the standard level of RBT dimension category. The *Procedural* is knowledge of the process and method of performing a task, which is more closely related to the specific practice of students than other knowledge levels (Jeon & Nam, 2018, pp.270). They also suggested that *Metacognitive knowledge* is cognitive knowledge, and if students do not realise that they do not know EK and methods, they will not want to learn new knowledge, and this needs to be emphasised more than other knowledge levels (Jeon & Nam, 2018, pp.270).

Table 4.8 Classification of EE-related content outcomes (n=18) in Korean secondary science syllabus (Years 7-10) according to the dimension of knowledge and cognitive processes in RBT

Cognitive / *Knowledge*	Remember	Understand	Apply	Analyse	Evaluate	Create	Number of knowledge items
Factual	-	-	-	-	-	-	**-**
Conceptual	-	7 (38.9)	2 (11.1)	-	1 (5.6)	-	**10 (55.6)**
Procedural	-	-	1 (5.6)	2 (1 1.1)	1 (5.6)	-	**4 (22.2)**
Metacognitive	-	-	1 (5.6)	-	3 (16.7)	-	**4 (22.2)**
Number of cognitive items	**-**	**7 (38.9)**	**4 (22.2)**	**2 (11.1)**	**5 (27.8)**	**-**	**18 (100)**

Percentages shown in round brackets (%)

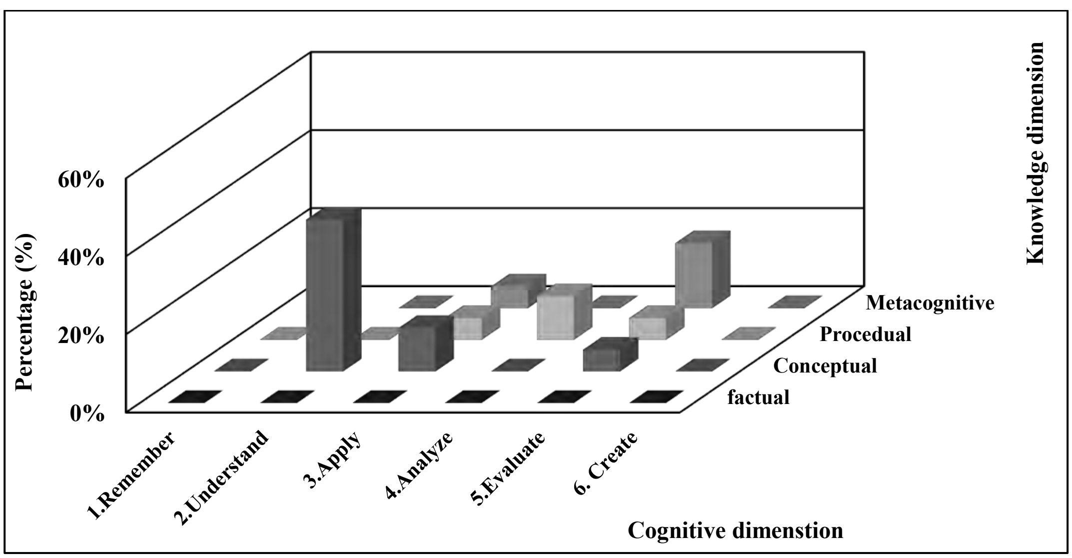

Figure 4.2 The classification of EE-related content outcomes (n=18) in the Korean secondary science syllabus (Years 7-10) according to the dimension of knowledge and cognitive processes dimension in RBT

In the Korean national science curriculum, the science content systematically constructs the core concepts in the areas of movement and energy, materials, life, and earth and the universe' and ensures that the core concepts and scientific inquiry are linked between middle school (Years 7-9) (MOE, 2015, pp.3). The scientific content of the integrated science (Year 10) fuses the constituent areas of existing science with movement and energy, materials, life, and earth and space and reconstructs them into the areas of matter and regularity, system and integration, change and diversity, and environment and energy (MOE, 2015, pp.91).

Based on the Korean national science learning areas, the distribution of EE content outcomes was examined from middle school science to integrated science. Table 4.9 shows that EE content outcomes were extracted from heat and energy, environment and ecosystem, and earth and space in the middle school science syllabus. In integrated science, EE content outcomes predominantly focused on e*nvironment and energy* (83.33 %). The Korean national science curriculum has the environment and energy units consist of two key concepts: environment and ecosystem and development of new renewable energy. This learning area, therefore, had the highest number of EE-related content outcomes within the integrated science syllabus.

Table 4.9 EE-related contents of science subject on middle school years (Years 7-9) and integrated science (Year 10) in Korean science curriculum

Year	Learning Area	Number of EE content outcome	Percentage
Years 7-9 (Science)	Force and motion	0	0.0
	Heat and energy	2	33.3
	Materials	0	0.0
	Life science	0	0.0
	Environment and ecosystem	1	16.7
	Earth and space	3	50.0
	Total	**6**	**100.0**
Year 10 (Integrated science)	Matter and regularity	0	0.0
	System and integration	0	0.0
	Change and diversity	2	16.7
	Environment and energy	10	83.3
	Total	**12**	**100.0**

Table 4.10 and Table 4.11 present that most of the EE content outcomes are biased in the *Understand* and *Conceptual categories*. In the cognitive process dimension, *Understand* and *Apply* cateries are the most frequently coded in the middle school science syllabus (Years 7- 9). The environment and energy learning area in the integrated science syllabus occurred in both *Understand* (16.7 %) and *Evaluate* (33.3 %), while nothing was coded as *Remember* or *Create*. The change in the cognitive process dimension may be viewed as more enforced in *Analysis* and *Evaluate* in higher grade levels. In the knowledge dimension, *Conceptual knowledge* occurred at 83.3 % in Years 7-10 science syllabus and 41.7 % at integrated science syllabus. Lee et al. (2015) reported that science learning objectives tended to be distributed in lower cognitive process such as *Remember* in the Korean national primary school science curriculum, indicating that middle school and integrated science curricula emphasise upgrading understanding about environmental concepts toward more creative thinking about the environment after the coverage of basic and factual contents of EK on the primary stage. To achieve the EE goals in school, the development of the contents of textbooks is essential to improve the students' EL. It has been rarely researched about content analysis of environmental-related curriculum. This study aims to be an initial approach to analyse the EE-related content outcomes in the secondary science curriculum.

Table 4.10 Cognitive dimension in RBT on Learning Areas of middle school science and integrated science syllabus

Year	Learning Area	Remember	Understand	Apply	Analyse	Evaluate	Create	Total
Years 7-9 (Science)	Force and motion	-	-	-	-	-	-	-
	Heat and energy	-	2 (33.3)	-	-	-	-	2 (33.3)
	Materials	-	-	-	-	-	-	-
	Life science	-	-	-	-	-	-	-
	Environment and ecosystem	-	-	1 (16.7)	-	-	-	1 (16.7)
	Earth and space	-	1 (16.7)	1 (16.7)	-	1 (16.7)	-	3 (50.0)
	Total	**-**	**3 (50.0)**	**2 (33.3)**	**-**	**1 (16.7)**	**-**	**6 (100.0)**
Year 10 (Integrated science)	Matter and regularity	-	-	-	-	-	-	-
	System and integration	-	-	-	-	-	-	-
	Change and diversity	-	1 (8.3)	-	-	1 (8.3)	-	2 (16.7)
	Environment and energy	-	3 (25.0)	2 (16.7)	2 (16.7)	3 (25.0)	-	10 (83.3)
	Total	**-**	**4 (33.3)**	**2 (16.7)**	**2 (16.7)**	**4 (33.3)**	**-**	**12 (100.0)**

Percentages shown in brackets (%)

Table 4.11 Knowledge dimension in RBT on Learning Areas of middle school science and integrated science syllabus

Year	Learning Area	Factual	Conceptual	Procedural	Metacognitive	Total
Years 7-9 (Science)	Force and motion	-	-	-	-	-
	Heat and energy	-	2 (33.3)	-	-	2 (33.3)
	Materials	-	-	-	-	-
	Life science	-	-	-	-	-
	Environment and ecosystem	-	1 (16.7)	-	-	1 (16.7)
	Earth and space	-	2 (33.3)	-	1 (16.7)	3 (50.0)
	Total	**-**	**5 (83.3)**	**-**	**1 (16.7)**	**6 (100.0)**
Year 10 (Integrated science)	Matter and regularity	-	-	-	-	-
	System and integration	-	-	-	-	-
	Change and diversity	-	2 (16.7)	-	-	2 (16.7)
	Environment and energy	-	3 (25.0)	4 (33.3)	3 (25.0)	10 (83.3)
	Total	**-**	**4 (41.7)**	**4 (33.3)**	**3 (25.0)**	**12 (100.0)**

Percentages shown in brackets (%)

4.1.2.3. Comparison of the Cognitive Dimension

One apparent commonality in both countries was, as mentioned above, the most EE content outcomes occurred in the *Conceptual* and *Understand* categories. Table 4.12 shows that most EE content outcomes were concentrated in *Understand* in the cognitive dimension in NSW (51.3%) and Korea (38.9%). Meanwhile, EE content outcomes occurred more in *Evaluate* in the Korean science syllabus than they did in NSW science. This may indicate that the level of EK in Korean EE may be structured higher than Australian EE based on the RBT analysis.

Table 4.12 Number of content outcomes in the cognitive dimension from Australian and Korean secondary science syllabi

Cognitive	Remember	Understand	Apply	Analyse	Evaluate	Create
Australian EE content outcomes (n=39)	6 (15.4)	20 (51.3)	6 (15.4)	3 (7.7)	4 (10.3)	**-**
Korean EE content outcomes (n=18)	-	7 (38.9)	4 (22.2)	2 (11.1)	5 (27.8)	**-**

Percentages shown in round brackets (%)

The EE-related topics that occurred in both countries' secondary science curricula were natural resources, energy, biodiversity (ecosystem), and environmental issues and sustainability. Table 4.13 shows the profile of the cognitive dimension in these topic areas.

Table 4.13 the distribution of content outcomes in the common content areas from Australia and Korea sorted according to cognitive processes

	EE content areas	Remember	Understan d	Apply	Analyse	Evaluate	Create
Australia	**Natural resources**	2 (5.1)	4 (10.3)	1 (2.6)	0 (0.0)	1 (2.6)	0 (0.0)
	Energy	0 (0.0)	4 (10.3)	2 (5.1)	1 (2.6)	0 (0.0)	0 (0.0)
	Ecosystem (biodiversity)	3 (7.7)	9 (23.1)	1 (2.6)	1 (2.6)	2 (5.1)	0 (0.0)
	Environmental issues and sustainability	1 (2.6)	3 (7.7)	2 (5.1)	1 (2.6)	1 (2.6)	0 (0.0)
Korea	**Natural resources**	0 (0.0)	0 (0.0)	1 (5.6)	0 (0.0)	1 (5.6)	0 (0.0)
	Energy	0 (0.0)	4 (22.2)	1 (5.6)	1 (5.6)	2 (11.1)	0 (0.0)
	Biodiversity (ecosystem)	0 (0.0)	2 (11.1)	2 (11.1)	0 (0.0)	1 (5.6)	0 (0.0)
	Environmental issues and sustainability	0 (0.0)	1 (5.6)	0 (0.0)	1 (5.6)	1 (5.6)	0 (0.0)

Following Porter alignment method (Porter et al., 2007), we produced topographical maps that displayed in the graphical form, how well cognitive/knowledge demands in the curricula in the graphical form. To make the two tables comparable, all cell values were standardised and converted into ratios totalling to 1 (Liu et al., 2009, pp.780). It allows more precise visualisation of their similarity/difference in the four common items. According to Figure 4.3, the difference of distribution items was Biodiversity (ecosystem) and Energy which was alignment ratio between 0.10 to 0.15 (the grey region) in *Understand* category. That is, the difference of distribution in *Understand* category from Biodiversity (Ecosystem) is 0.12, indicating the high level of absolute discrepancy between NSW and Korean curriculum. *Understand* the category from *Energy* is also 0.12. This shows that EE content outcomes in NSW science occur more frequently in Biodiversity (Ecosystem), while EE content outcomes in Korean science occur more frequently in Energy.

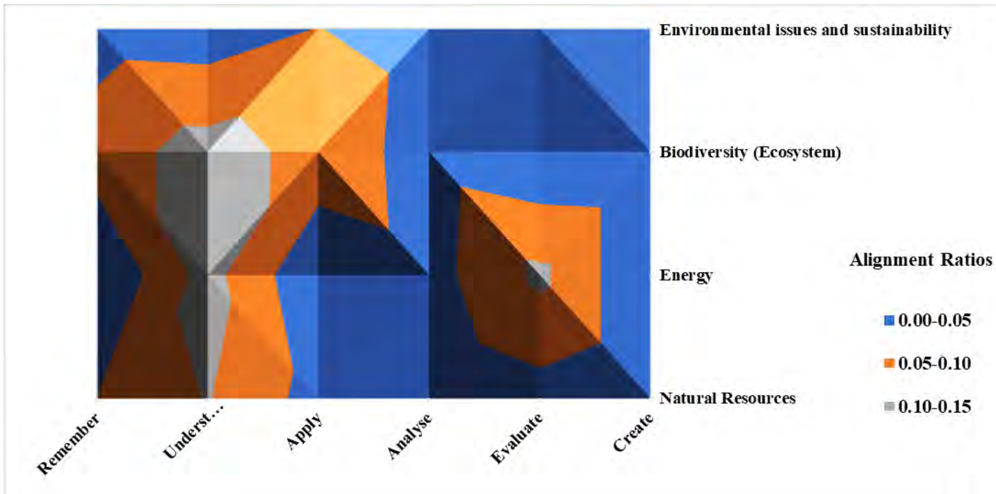

Figure 4.3 Topographic map showing the distribution of EE-related content outcomes from Australian and Korean secondary science syllabi in the cognitive dimension of RBT

4.1.2.4 Comparison of the Knowledge Dimension

Table 4.14 shows that the *Conceptual* category has a high percentage in NSW EE content outcomes (82.0 %) while the other three knowledge categories generated with low percentage the ranging from 5.1 % to 7.7 %. No outcomes were found in the *Factual* knowledge and *Remember* categories. As mentioned above, there are separated environmental textbooks in the Korean primary and secondary national curricula. It is expected that the simple knowledge and experiences about environment may deliver and incorporate from *Factual* in Primary course and *Conceptual*, *Procedural*, and *Metacognitive* knowledge are required as the grade level increases.

Table 4.14 Number of content outcomes in the knowledge dimension from Australian and Korean secondary science syllabi

Knowledge dimension	Factual	Conceptual	Procedural	Metacognitive
Australian EE content outcomes (n=39)	2 (5.1)	32 (82.0)	2 (5.1)	3 (7.7)
Korean EE content outcomes (n=18)	-	10 (55.6)	4 (22.2)	4 (22.2)

Table 4.15 shows the profile of the knowledge dimension in similar topic areas. Most environmental topic areas were concentrated in the *Conceptual* category. Alignment measurement was also conducted to compare the frequency of the knowledge dimension

between Australian and Korean EE content outcomes in science syllabi. Figure 4.4 shows that the difference of distribution items for Biodiversity (ecosystem) had an alignment ratio between 0.10 to 0.15 (the grey region) in the *Conceptual* category with 0.14. The energy topic was in the grey region and was also present in the *Metacognitive* category with 0.11, indicating that Korean EE content outcomes have a higher level in the energy curriculum than those in NSW.

Table 4.15 the distribution of content outcomes in the common content areas from Australia and Korea sorted according to Knowledge dimension

	EE content areas	Factual	Conceptual	Procedural	Metacognitive
Australia	Natural resources	1 (2.6)	6 (15.4)	0 (0.0)	1 (2.6)
	Energy	0 (0.0)	6 (15.4)	1 (2.6)	0 (0.0)
	Biodiversity (ecosystem)	0 (0.0)	14 (35.9)	1 (2.6)	1 (2.6)
	Environmental issues and sustainability	1 (2.6)	6 (15.4)	0 (0.0)	1 (2.6)
Korea	Natural resources	0 (0.0)	1 (5.6)	0 (0.0)	1 (5.6)
	Energy	0 (0.0)	4 (22.2)	2 (11.1)	2 (11.1)
	Biodiversity (ecosystem)	0 (0.0)	4 (22.2)	1 (5.6)	0 (0.0)
	Environmental issues and sustainability	0 (0.0)	1 (5.6)	1 (5.6)	1 (5.6)

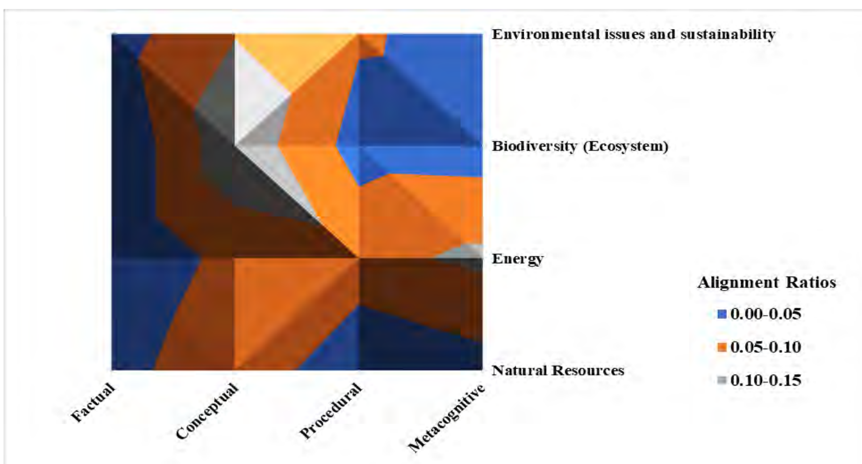

Figure 4.4 Topographic map showing the distribution of EE-related content outcomes from NSW and Korean secondary science syllabi in the Knowledge dimension of RBT

In summary, EE-related content outcomes between Australian and Korean secondary science syllabus were analysed by using RBT. The greatest number of intended environmental content outcomes for secondary science in Australia and Korea were clustered the *Understand/Conceptual* categories group. No *Create* category was not coded from both countries. In the category of *Create*, students are expected to devise novel or different thinking or methods by adapting environmental knowledge, which is often challenging tasks. The aim of the study is the assessment of EL based on the proportional relationship from EK to EA development within science syllabus. It is premature to conclude that EK, which are mostly focused on a low level of learning objectives like *Understand/ Conceptual* structure impacts the level of students' EA.

4.2 Environmental literacy assessment in secondary science context

The ELTSQ was developed based on the various prior instruments (e.g., Wisconsin Centre for Environmental Education, 1997; DeChano, 2006; Smith, 2014; Chu et al., 2007; Erdogan & Marcinkowski, 2015) through the assessment of curriculum analysis of science subject from both the Australian and Korean science curricula. Unlike other EL assessment questions which never have been referred from the contents analyses, the ELTSQ was designed based on the results of RBT that have been analysed from Australian and Korean secondary science learning outcomes. The preliminary testing of ELTSQ was conducted to determine whether the questionnaire was appropriated for measuring students' EL, especially their EK and EA in this study. The evaluation of students' EK and EA was also conducted with the aim of showing that a higher level of EK learned in the science curriculum resulted in the more positive the EA.

4.2.1 Validity and reliability of the ELTSQ

Validity: In this study, various types of validation processes were performed to evaluate the validity of the ELTSQ. Firstly, the content validation of the ELTSQ conducted by three experts who majored in EE. A 4-point Likert scale with an agreement questionnaire for the expert's content validation were prepared, and three science/environmental education experts were invited to provide their quantitative responses. Table 4. 16 shows the content validity index (CVI) system for both EK and EA scales (Lynn, 1986, Lee et al., 2016, pp. 34). The overall

CVI was more than 0.9. The CVI scores for all the items ranged from 0.83 to 1.0 so that most of these items were found to be at an adequate question for the assessment of students' EK and EA. The face validity was also performed by the experts who read and discussed the appropriateness of the knowledge and attitudes questions on each scale. Based on feedback from the experts, the item statements were modified and amended. The semi-structured interview was also designed to support the validation of the ELTSQ. The interview questions were selected based on findings and discussion from the previous pilot studies (Kopnina et al., 2012; Lawton, 2016). The author indicate that these beliefs/attitude questions in NEP sub-scale in EA were too general to confirm that students' responses to the questions were aligned with the item that the questionnaire developers intended to measure. The authors, however, also insisted on the need for interviewing students using such beliefs/attitude items. The semi-structured interviews were conducted with four students to ensure that the participants could fully comprehend the questionnaire items. The purpose of the semi-structured interviews was to support the validity of the EA questionnaire and determine whether students understood each EA item/question.

Table 4.16 Content validity index of each item category

Scales, Sub-scales, Item category	CVI of Scale, Sub-scale, Item category			The total mean of CVI
	Expert 1	Expert 2	Expert 3	
Environmental knowledge	1.00	1.00	1.00	1.00
Ecological knowledge	1.00	1.00	1.00	1.00
Natural resources	1.00	1.00	1.00	1.00
Energy	1.00	1.00	1.00	1.00
Biodiversity (ecosystem)	1.00	1.00	1.00	1.00
Knowledge of environmental issues	1.00	1.00	1.00	1.00
Environmental issue	1.00	1.00	1.00	1.00
Environmental sustainability	1.00	1.00	1.00	1.00
Environmental attitude	1.00	0.78	1.00	0.93
NEP	1.00	0.81	1.00	0.94
Right of nature (NRN)	1.00	1.00	1.00	1.00
Eco-crisis (NEC)	1.00	0.60	1.00	0.87
human exemptionalism (NHE)	1.00	0.83	1.00	0.94
Disposition	1.00	0.75	1.00	0.92
Environmental sensitivity (DES)	1.00	1.00	1.00	1.00
Environmental concern (DEC)	1.00	0.75	1.00	0.92
Environmental responsibility (DER)	1.00	0.50	1.00	0.83

Reliability: To determine the scales' reliability for the evaluation of the ELTSQ as an appropriate tool to assess EK and EA, Cronbach's alpha reliability coefficient was calculated for each scale. Cronbach's alpha results range from 0 to 1. The general rule for an acceptable score is that it should be over 0.7. The overall reliability for EK was 0.928 in Years 7 - 8 and 0.921 in Years 9 - 10, and the reliability of EA was 0.805 in Years 7 and 8 and 0.809 in Years 9 and 10, showing that the EK and EA questionnaire can be considered significantly acceptable for the knowledge and attitudes scale of the ELTSQ. The reliability coefficient was also found to be 0.874 in Years 7 and 8 and 0.830 in Years 9 -10 on the ecological knowledge subscale and 0.879 and 0.895 in the knowledge of environmental issues, respectively. For the *NEP* and *disposition* subscales in EA, Cronbach's alpha was also acceptable for their reliability. In conclusion, the ELTSQ tool is highly acceptable as a measure of secondary students' EK and EA. The details for the reliability of each subscription are shown in Tables 4.17 and 4.18. With the designed ELTSQ, this study basically planned to perform in Australian and Korean secondary school students. However, the assessment of EK and EA in Australian secondary students was not able to perform in the short term. More details are written in the conclusion chapter as a limitation and further study. Only the outcomes of Korean secondary students were reported in this study.

Table 4.17 Cronbach's alpha reliability in environmental knowledge for Korean secondary students

Scale, Sub-scale, Item category	Reliability (Cronbach's Alpha)	
	Years 7-8 (n= 146)	**Years 9- 10 (n= 233)**
Environmental knowledge	**0.928 (37)**	**0.921 (50)**
Ecological knowledge	**0.874 (19)**	**0.830 (25)**
Nature Resources (ECNR)	0.565 (5)	0.281 (5)
Energy (ECE)	0.673 (7)	0.594 (8)
Biodiversity (Ecosystem) (ECB)	0.843 (7)	0.801 (12)
Knowledge of environmental issues	**0.879 (18)**	**0.895 (25)**
Environmental issue (EI)	0.815 (10)	0.820 (14)
Environmental sustainability (ES)	0.773 (8)	0.828 (11)

No. of questions was shown in the bracket.

Table 4.18 Cronbach's alpha reliability in environmental attitudes for Korean secondary students

Scale, Sub-scale, Item category	Reliability (Cronbach's Alpha)	
	Years 7-8 (n= 146)	**Years 9- 10 (n= 218)**
Environmental attitude	**0.805 (23)**	**0.809 (23)**
NEP	**0.563 (14)**	**0.676 (14)**
Right of nature (NRN)	0.492 (4)	0.514 (4)
Eco-Crisis (NEC)	0.721 (4)	0.711 (4)
human exemptionalism (NHE)	0.664 (6)	0.701 (6)
Disposition	**0.882 (8)**	**0.862 (8)**
Environmental sensitivity (DES)	0.751 (3)	0.820 (3)
Environmental concern (DEC)	0.510 (2)	0.828 (2)
Environmental responsibility (DER)	0.847 (3)	0.804 (3)

No. of questions was shown in the bracket.

4.2.2 Environmental knowledge and environmental attitudes assessment in Korean secondary students

The participants in this study were Korean secondary students in Years 7 and 8 (*n* = 146) and Years 9 and 10 (*n* = 233). The ELTSQ test was composed of two scales: EK and EA. Frequency distribution and the reliability of each scale were analysed. The correlation coefficient was also evaluated based on the research question of what relationship was formed between the students' average scores on each component of the EK and EA scales.

4.2.2.1 Environmental knowledge

EK consists of two sub-scales, *Ecological Knowledge* and *Knowledge of environmental issues,* as mentioned in the methodology chapter. The mean percentage of correct answers about EK are presented in Table 4.19. The overall mean percentage of EK was 40.4 % in year 7-8 Korean students and 54.4 % in year 9-10 students. The level of EK was generally higher in years 9-10 students than year 7-8 students. The mean percentage of correct responses between two sub-scales, *Ecological knowledge* (42.9 %) and *Knowledge of environmental issues* (37.9 %), was slightly different in years, 7-8 Korean students. The students had more knowledge of *Ecological knowledge* than *Knowledge of Environmental issues* sub-scale. A similar phenomenon was also shown in years 9-10 students' mean percentage of correct responses. The ELTSQ revealed a higher score for the Biodiversity and Energy categories compared to the Natural Resources category in the Korean secondary students' EK assessment. In terms of the number of learning outcomes related to EK content in the Korean secondary science curriculum, biodiversity (ecosystem) and energy were major items, whereas natural resources-related content was not the major category for Years 7–10 Korean science subjects. In spite of the result above, the lowest rate of correct answers about *Ecological knowledge* was in the question of '*which of the statements on energy transformation below is not correct?*' with only about 5 % in years 7-8 students. The interesting thing was that the percentage of the correct answer for this question was only about 13 % in year 9-10 Korean students (Appendix II). The question must be involved in one of the learning outcomes in the Energy section in Korean secondary science curriculum. It is important consideration how deliver the science knowledge to students based on the current science syllabus. Among the items addressing Knowledge of environmental issues (KEI), it emerged that the knowledge about environmental sustainability (ES) was lower than the knowledge about environmental issues (EI) among Korean students in Years 7–8. Judging by secondary school science syllabi, most EE-related content is focused on ecological or environmental issues. The middle school environmental education subject curriculum has added awareness of environmental sustainability as an aim (Kim, 2015). Lee et al. (2017) reported that only about 10 % of students select the optional environmental subject . This situation may have influenced the result that the mean score of EI is higher than that of ES. Table 4.20 presents the means and standard deviations of EK. The analysis of *t*-test results of Years 7-8 and Years 9-10 Korean students showed a statistically significant difference of $p < 0.01$. This implies that the EK of Years 9-10 students is significantly higher than the EK of Year 7-8 students.

Table 4.19 The mean percentage of correct answers in the environmental knowledge scale on the ELTSQ

Scale/Sub-scale/Item category	Mean percentage of correct responses	
	Years 7-8 (n= 146)	**Years 9- 10 (n= 233)**
Environmental knowledge	40.4	54.4
Ecological knowledge (ECK)	42.9	58.4
Natural resources (ECNR)	33.0	54.2
Energy (ECE)	40.5	56.1
Biodiversity (ecosystem)(ECB)	52.3	60.4
Knowledge of environmental issues (KEI)	37.9	50.4
Environmental issue (EI)	41.4	51.1
Environmental sustainability (ES)	33.5	49.4

Table 4.20 Summary of independent t-test for Environmental Knowledge between year 7-8 and year 9-10 Korean students

Scale, Sub-scale, Item category	Mean ± SD		t (2-tailed)
	Years 7-8 (n= 146)	Years 9- 10 (n= 233)	
Environmental knowledge	0.40 ± 0.24	0.54 ± 0.21	5.940**
Ecological knowledge (ECK)	0.43 ± 0.25	0.58 ± 0.20	6.514**
Knowledge of environmental issues (KEI)	0.38 ± 0.25	0.50 ± 0.24	4.680 **

*** the t-test value P < 0.01*

4.2.2.2 Environmental attitudes

Students' EA can extend beyond their interests encompassing dispositions toward selected aspects of the environment and environment-related matters (e.g., Marcinkowski, 1989; Hollweg et al., 2011, pp.306). The EA of students was measured using two sub-scales, consisted of 16 items of NEP and 12 items of *Disposition*. The sub-scales of *NEP* are *Right of nature (NRN)*, *Eco-crisis (NEC)*, and *Human-exemptionalism (NHE)*. NRN questions were mainly adapted from *Anti-anthropocentrism,* that is, the belief of humans that they can change and control the environment (Dunlap et al., 2000). NEC is the belief that humans cause environmental damage. NHE is adapted from Anti-exemptionalism, the belief that humans are responsible for preserving nature (Manoli et al., 2007; Dunlap et al., 2000). The sub-scale of *Disposition* composes *environmental sensitivity* (DES), *environmental concern* (DEC), and *environmental responsibility* (DER). During the analysis, the questions, NRN1, DES4, DEC3 and DEC4, and DER 4 were interrupted for the reliability of each scale. Therefore, they were to be decided to be eliminated. Some questions were reversed coded due to the negative meanings.

The mean percentage of positive responses about EA is presented in Table 4.21. Unlike the EK's score, which measures correct answers on a binary scale, EA is Likert-type scale with agreement level from 1 to 6. Five or 6 were regarded as a positive response and mean percentage was calculated by using a binary scale with '1'. The overall mean percentage of EA was approximately 50 % in both Years 7-8 and Years 9-10 students. Among the item categories of *NEP*, *Eco-crisis* had the highest percentage to compare the other two sections. On the other hand, the mean percentage of positive responses in *Human-exemptionalism* is low in all students.

Unlike other EA questions, the *Human-exemptionalism*-related questions were originally created in the form of opposite meaning to their original concept of Anti-anthropocentrism. While we were coding the responses, we went through the reverse coding order and analysed them. These types of questions may need to be reconsidered in order to make them easier for secondary students to comprehend. The interesting point is that the most EE related content outcome in secondary science syllabi focused on elements of the Eco-Crisis such as 'global warming' or 'devastation of habitats arising from humans' development impact on the environment'. Therefore, students received the highest scores in these areas on the Knowledge scale. This result may have been influenced by the current syllabus and its elaboration. The frequency of positive responses for each item in the EA is shown in Appendix III. Table 4.22 presents the results of the independent *t*-test showing that no significant difference between Years 7-8 and Years 9-10 students' EA. With a result, the design of EA questions should be more considered to develop the quality of EA section in ELTSQ.

Table 4.21 The mean Percentage of positive responses in the environmental attitudes scale on the ELTSQ

Scale, Sub-scale, Item category	Mean percentage of correct responses	
	Year 7-8	**Year 9- 10**
Environmental Attitudes	50.9	49.3
NEP	50.1	51.1
Right of nature (NRN)	50.7	51.5
Eco-Crisis (NEC)	64.4	61.5
human exemptionalism (NHE)	37.8	42.1
Disposition	51.8	47.3
Environmental sensitivity (DES)	52.5	49.9
Environmental concern (DEC)	55.5	42.7
Environmental responsibility (DER)	48.6	47.8

Table 4.22 Summary of independent *t*-test for environmental attitudes between years 7-8 and years 9-10 Korean students

Scale/Sub-scale/Item category	Mean ± SD		t (2-tailed)
	Year 7-8 (n= 146)	**Year 9- 10 (n= 233)**	
Environmental Attitudes	0.50± 0.24	0.51 ± 0.26	0.336
NEP	0.50± 0.23	0.51 ± 0.26	0.385
Disposition	0.52 ± 0.34	0.47 ± 0.34	1.245

4.2.3 Correlations between environmental knowledge and environmental attitudes

A correlation analysis was carried out to evaluate the relationship between EK and EA in Korean secondary students (Table 4.23). The tables below show that this was meaningfully represented through a diagram with the Pearson correlation coefficient being above 0.3, which concisely expresses medium and large strength of correlations between scales (Samuels, 2014). It shows that the overall significant correlation between EK and EA is 0.351. As students have more knowledge toward the environment, they have levels on the *NEP* sub-scale which was developed to evaluate environmental beliefs and perspectives as an affective component of EL, but they do not have higher levels of the *Disposition* sub-scale, which was structured as another attitude sub-scale designed by NAAEE based on the Simmons' framework (Hollweg et al., 2011; Simmons, 1995). According to Hollweg et al. (2011), EL in the present NAAEE framework is composed of five types of knowledge including three from Simmons's framework with another two new knowledge sections added: multiple solutions to environmental issues and citizen participation and action strategies. The EK scale in ELTSQ was limited to two sub-scales, ecological and environmental issue, which were categorised initially in Simmons's framework. Further research into the correlation between citizen participation and action-related knowledge and *Disposition* needs to be done.

Table 4.23 The correlations between environmental knowledge and environmental attitudes on the ELTSQ (Years 7-10)

# Correlation between EK & EA (**0.351****)		**Environmental knowledge (EK)**		**Environmental attitudes (EA)**	
		ECK	*KEI*	*NEP*	*Dis*
Environmental knowledge (EK)	*ECK*	1			
	KEI	0.746**	1		
Environmental attitudes (EA)	*NEP*	0.359**	0.429**	1	
	Dis	0.143**	0.147**	0.425**	1

ECK: ecological knowledge, KEI: knowledge of environmental issues, NEP: new ecological paradigm, Dis: disposition.
*** Correlation is significant at the 0.01 level (2-tailed).*

Table 4.24 shows the correlations among each item category group in the EK scale of the ELTSQ. Two item categories in the *Ecological knowledge* sub-scale have a lower correlation with the environmental sustainability item category than with the environmental issues item category; in particular, the correlation between natural resources (ECNR) and environmental sustainability (ES) was the lower compared to other correlation. For example, the lowest number of students (16 %) in the question '*Approximately 70 % of all freshwater withdrawn for human use in used for*' was Irrigation as a correct answer. The question was decided as a primary question to develop the students' knowledge of ES. The curriculum analysis showed that a lack of knowledge about natural resources was observed in the Korean secondary science curriculum, although UNESCO has promoted the education of sustainable development (ESD) in EE, the Korean Ministry of Environment has made active effort to add ESD to science curricula (MOE, 2015). More sophisticated questionnaire instrument should be evaluated and developed to assess the natural resources to link ES for further research.

Table 4.24 Correlations between item categories of environmental knowledge on the ELTSQ (Years 7- 10)

	ECNR	**ECE**	**ECB**	**EI**	**ES**
ECNR	1				
ECE	.519**	1			
ECB	.491**	.654**	1		
EI	.476**	.607**	.722**	1	
ES	.469**	.511**	.601**	.733**	1

The abbreviated names are the name of the item question group. ECNR, ECE, and ECB are belonging to Ecological knowledge sub-scale, and EI and ES belong to Knowledge of environmental issues sub-scale
*** Correlation is significant at the 0.01 level (2-tailed).*

Table 4.25 presents the correlations among each item category group in the EA scale of the ELTSQ. Most EA item categories have significantly correlated with each other except the correlation between all EA questions and *Human-exemptionalism* (NHE), especially in Years 9-10. As mentioned above, the structure of the NHE questions was the opposite of the original meaning. It is noted that this question type was not proper for students to understand, so a more revised *NEP* structure is necessary.

Table 4.25 The correlations between item categories of environmental attitudes on ELTSQ (Years 7-10)

	NRN	NEC	NHE	DES	DEC	DER
NRN	1					
NEC	.530**	1				
NHE	-.174**	-0.06	1			
DES	.467**	.548**	-.126*	1		
DEC	.431**	.426**	-.160**	.559**	1	
DER	.473**	.440**	-.148**	.715**	.608**	1

The abbreviated names are the name of the item question group. NRN, NEC, and NHE are belonging to NEP sub-scale and DES, DEC, and DER belong to Disposition sub-scale.
*** Correlation is significant at the 0.01 level (2-tailed).*

4.3 Summary of results

To design a better ELTSQ, we validated the ELTSQ with three validation processes: curriculum/syllabus analysis, experts' content and face validation, and student interviews. The RBT analysis, as the part of content validation processes, showed that most EE-related content outcomes were grouped in the 'understand' category in the cognitive process dimension and the 'conceptual' category in the knowledge dimension in both NSW and Korean science curricula/syllabi. Another interesting result showed that there was no 'create' category in any EE-related content outcomes from both countries' science curricula/syllabi, showing that environmental classes that meet creative goals are not adequately reflected in science classes. As the school year progressed, the level of cognitive process and knowledge dimensions became higher, but outcomes in the 'create' and 'metacognitive' categories group, regarded as the highest level in the subjects' syllabi, were still far from sufficient to improve the students' high level of EL. This indicates that the goals for EE in Australia and Korea are inconsistent in terms of understanding environmental issues and improving EL through creative and scientific problem-solving skills.

Based on the results of RBT, the EK-related questions in the ELTSQ were collected and modified. For EA-related questions in the ELTSQ, most of the questions were prepared based on collecting the components of the NEP scale and the existing attitude questions that are related disposition scaled by NAAEE (Hollweg et al., 2011). The experts' content and face validation were performed before the survey with the ELTSQ to determine that each question was acceptable and adjustable to secondary school students. CVI results show that all three experts agreed on the item questions in the EK scale, but the agreement range for the items in the EA scale was 0.7–0.9. Semi-structured interviews of students were also conducted to ensure that participants had fully comprehended the questionnaire items. They also accepted the ELTSQ reliability by their positive response to the interview questions that were targeted to assess the students' EL.

The ELTSQ was given to Years 7-10 Korean students (147 in Years 7 and 8 and 233 in Years 9 and 10), and Cronbach's alpha reliability, frequency distribution using the mean percentage of correct/positive responses, and the correlation between EK and EA were assessed and evaluated. The EK and EA scales showed high Cronbach's alpha reliability at 0.80– 0.92. The results showed that the EK scale had 40.4% of the mean percentage of correct responses in Years 7 and 8 and 54.4% in Years 9 and 10. Moreover, the lowest mean percentage of correct responses were in the natural resources item category in the ecological knowledge sub-scale (ECNR; 33. 5%). This result can be linked to the results of the curriculum/syllabus analysis using RBT. The Korean science curriculum analysis indicated that there were not many EE-related learning outcomes in Years 7 and 8 related to natural resources science content (only 11%). For the EA scale on the ELTSQ, the mean percentage of positive responses was approximately 50% from both Years 7 and 8 and Years 9 and 10.

An independent t-test was conducted to compare the difference between Years 7 and 8 and Years 9 and 10 student responses on the EK and EA scales in the ELTSQ. The results revealed that there was a significant difference between students in Years 7 and 8 and Years 9 and 10 (Years 7 and 8, 0.4 ± 0.24; Years 9 and 10, 0.54 ± 0.21; $t = 5.95$, $p = 0.00$) on the EK scale. On the other hand, there were no significant school-year differences on the EA scale (Years 7 and 8, 0.50 ± 0.24; Years 9 and 10, 0.51 ± 0.26, $t = 0.34$, $p = 0.74$).

In the correlation between EK and EA, the sub-scales in EK and EA significantly correlated with each other. The lowest correlation in this study ($r = 0.14$) was that between ecological knowledge (one of the EK sub-scales) and disposition (one of the EA sub-scales). This indicates that students' EA, especially environmental sensitivity, concern and responsibility, does not affect current environment-related knowledge in science contexts. Previous research has reported that environmental responsibility is associated with metacognitive processes that lead students to avoid environmental behaviours that contribute to negative environmental impacts (e.g., Bamberg & Moser, 2007; Hines et al., 1986, 1987; Hollweg et al., 2011, pp. 3-6).

CHAPTER FIVE: CONCLUSION

5.1 Research Conclusion

The purpose of this study was to develop an EL assessment test (ELTSQ) for secondary students in science subjects. The study specified to find the solution based on the research questions below;

"How are the EE-related content outcomes organised in cognitive terms in Australian and Korean secondary science curricula?" was a beginning question to design and develop the ELTSQ. As the results were mentioned in results and discussion chapter, current learning outcomes which are related EE in science curriculum was mainly categorized with "Understand" in cognitive process and "Conceptual" in knowledge dimension in both Australian and Korean secondary science syllabi according to the RBT analysis. The Leaning aims in both Australian and Korean science curricula contain the understanding of nature and concept science based on interest and curiosity for natural phenomena (NESA, 2018; MOE, 2015). The 7th Korean national curriculum also emphasizes creative thinking skills and communication skills. However, wee et al. (2011) reported that the Korean leaning outcomes are not appropriately matched to the creative problem solving compared to the 7th curriculum. This suggests that all environmental educators and teachers should consider expanding creative processes and metacognitive knowledge in the broad range of curriculum in the school-based EE system. One suggestion is the exploration and development of environmental courses and textbooks that are relevant to the curriculum of each stage and include allowing students to assess or evaluate their knowledge at each grade level.

Referring to Research Question 2, "Is the EL assessment tool valid and reliable for secondary school students?", it can be concluded, based on our analysis of the Korean students' responses, that using the three-step validity process, i.e. content validation using Anderson's Revised Blooms Taxonomy, face-validation and student interviews, helps researchers produce a valid and reliable instrument which can assess secondary students' EK and EA. There should be follow-up in the form of further investigation in order to implement the developed ELTSQ across the two countries of Korea and Australia.

“What are the students’ levels of EK and EA in Australia and Korean secondary students?” is the 3rd research question in this study. The overall mean sub-scale scores in EK, ecological knowledge (ECK) and knowledge of environmental issues (KEI) were moderate (see p.61) Especially mean score of the ecological knowledge sub-scale was slightly higher than the mean score of the knowledge of environmental issues sub-scale in Years 7–10 Korean students. This finding was similar to findings in previous studies (Lee et al., 2004; Choi, 2014). Although the overall mean score of Korean secondary school students was not outstanding, the findings indicated that the ELTSQ is capable of measuring the environmental literacy levels of the Korean students in Years 7-10 with regard to what they had learned in the science classroom, based on the secondary school science curriculum. The overall positive responses about EA was also similar to the mean score of EK where identified in 4.2.2.2 Environmental attitude (see p.63). These positive responses were also not big different from the previous report (Lee et al., 2014). It was interesting that the highest positive response was for the Eco-Crisis related sub-scale. It may be cautiously predicted that the reason for this is that currently existing science classes have focused only on environmental problems. If EE focuses more on how to solve these environmental problems, it is suggested that the level of students’ concern or sense of responsibility toward the environment will develop. Even though I cannot conclude the Australian students’ level of EA and EK at this time due to the research limitation of this study (see p.10), I can conclude that school science curriculum influences students’ EK and EA from the research findings as other researchers reported in their studies (Lee et al., 2004; Chu et al., 2007; Abdullah et al., 2011). The Australian data will be collected in 2020, and the cross-country comparison study will provide us with a clear answer related to the level of EK and EA in each country.

In the case of the research question, four is “Is the current science syllabus influent to secondary school students’ EK and EA?”. It can be concluded that the current science syllabus has a direct influence on students’ EA. In the case of some of the EA questions, such as ‘If things continue the same way they are now, we will face a huge environmental disaster’, most of the students agreed. This means that student EA may be influenced by EE-related content and elaboration.

The research question five, “What is the correlation between EK and EA in secondary school students?”, was considered from Korean secondary students in the results and discussion chapter, EK was correlated to EA, especially NEP scale, although the overall level of each EK and EA are moderate. To prove this result, the study will have a plan the assessment of Australian secondary students' EK and EA as a further study due to that the study was not able to perform with the time limitation of this study period.

In conclusion, based on our findings on Korean students' EK and EA, the ELTSQ is confirmed as a potential tool for science educators and teachers in the science classroom to assess secondary school students' EK and EA in science contexts. The design of this questionnaire has focused on the cross-national dimension, using RBT analysis to achieve EE related content outcomes. The questionnaire development process, including Anderson's Revised Blooms Taxonomy as part of the content validation, can project a clear vision of the similarities and differences between school science curricula across countries. The curriculum analysis using RBT helped the researchers to prepare the questionnaire within the framework of the learning outcomes/content outcomes and to produce a questionnaire that was balanced fairly across two countries.

The data on the Australian secondary school students' EK and EA could not be collected within the Master's research timeframe, due to the schools' lack of interest in EL studies in the science classroom This limitation does not fully detract from the study overall nor from its outcomes. The item validation process (curriculum analysis, face- validation and student interviews) and the findings from the item analysis (reliability and scale, and mean score calculations, as well as correlation analysis) as applied to the Korean students' data provided items that could reasonably be used across the two countries; and the outcomes of this item analysis could be used to further improve the ELTSQ before collection of the Australian students′ data.

5.2 Research implications

Despite the great diversity of EE programs around the world, there is a common feature among all of them: a lack of evaluation of their effectiveness to reach their goals, which are to promote more knowledge, better attitudes and a higher prevalence of pro-environmental behaviours (Disinger & Roth, 1992; Spinola, 2015, p. 406). The ELTSQ was designed to examine and reflect on science curricula analysis, RBT, and become a useful tool for providing better students' EL. This questionnaire is a first attempt to provide a more accurate assessment of students' EL. We encourage all researchers and educators to consider the assessment and modification of EL education using the ELTSQ to advance EE research with attention to the EE content within science curricula and classes.

5.3 Further research

This study aimed to create a higher quality EL assessment tool. More work needs to be done through further studies in the near future that can investigate students' EK and EA across Korea and Australia, as follows: 1) collecting larger samples than in the current study, including Australian students, 2) the application of alternative item validation processes (e.g. Factor Analysis), and Item Analysis using a higher level of statistical analyses (e.g., Path Analysis or Regression Analysis. All scales of EL are interrelated (Chu et al., 2007). The correlations among students' EK, environmental skills, EA and environmental behaviour are also essential to consider in helping achieve a higher quality of student EL in the science curriculum.

As mentioned in the section on the limitations of the study, Australian secondary students' EK and EA data could not be collected during the study, so there will be follow-up research studies. The Australian students' data will be collected and combined with the existing Korean data to investigate how the developed ELTSQ measures students' EL in science contexts across two countries in 2020.

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APPENDICES

Appendix I: Environmental Literacy Test for Secondary School Students

Environmental Literacy Test (ELT)

We are science education research team at Macquarie University. This is a survey designed to help us understand the levels of environmental literacy of both Australian and Korean secondary school students. We are measuring students' knowledge and attitude about the environment. The environmental knowledge section includes multiple-choice questions that assess students' knowledge about basic ecological concepts and local and global environmental issues. In the environmental attitude section please make your selection based on the strength of your agreement with each question. Responding to this questionnaire indicates that you have agreed to participate in this research project. It may take about 35-40 minutes.

Please take your time to answer each question as best you can.

Student Information

Below are some basic questions aimed at gathering demographic information. This data will not be used for any purpose other than this research.

1. My gender: □ Female □ Male □ Other □ Prefer not to say

2. My school type (check one):

   □ Public □ Private (Catholic) □ Private (Anglican)
   □ Private (Uniting Church) □ Private (Non-denominational)

3. What year are you in at school?

   □ Year 7 □ Year 8 □ Year 9 □ Year 10

4. My science grades are often: □ Low □ Average □ High

5. What are your parents' occupations/jobs?

   (e.g., housekeeper, lawyer or construction worker. If you would prefer not to fill in this section, just write 'no comment'.)

   Mother ________________________ Father ________________________

6. In what type of housing are you living?

□ An apartment □ A unit □ Town house □ A house □ No comment

7. How many science books are there at your home?

□ Less than 10 □ 10 to 25 □ 25 to 50 □ More than 50

8. How concerned are you personally about environmental problems?

□ A lot □ A fair amount □ A little □ Not at all

9. I am interested in what I learn about the environment in class.

□ Strongly agree □ Agree □ I am not sure □ Disagree □ Strongly disagree

10. What one thing has contributed most to your understanding of the environment and environmental issues?

□ School
□ Books, newspapers or magazines I have read on my own
□ Friends or family members (including parents)
□ Field trips, special programs or activities such as clubs
□ TV programs

11. How many times per week are you attend science class at your school?

□ Less than one (e.g., one time per school term)
□ One to two
□ Three to four
□ More than four

12. How often does your school have an environmental class or activity?

□ At least once a year
□ At least once a month
□ At least once a week
□ I am not sure

13. Are you satisfied with the school environmental program?

□ Excited
□ Satisfied
□ Unsatisfied
□ Very bored
□ I am not sure

Environmental Literacy Assessment (Knowledge Questionnaire)

The Questionnaire to assess Environmental Literacy in Secondary School Students (ELTSQ), developed by the project research team, will be used to measure students' environmental knowledge. The knowledge questionnaire is divided into two sections on ecological knowledge (EC) and environmental issues (EI). EC consists of questions about natural environmental resources (ECNR), Energy (ECE), Biodiversity and ecosystem (ECB). EI section covered students' understanding of the environmental issue and the knowledge of environmental sustainability (ES).

Please read these questions and choose an answer.

Section One. Ecological knowledge: Understanding of ecological concepts involving how natural systems work

ECNR1. Which of these materials are made from renewable natural resources?

a) Plastic
b) Nylon thread
c) Polyester
d) Leather
e) I do not know.

ECNR2. Why are the fossil fuels coal, oil and gas known as non-renewable resources?

a) Because they are limited: Once they are used, they are gone forever
b) Because they are man-made resources
c) Because they occur naturally and are available in unlimited amounts
d) Because they take hundreds of millions of years to form
e) I do not know.

ECNR3. What is the water cycle?

a) The process followed at desalination plants
b) The natural recycling of water on Earth
c) The scientific name for rain, hail and snow
d) The natural conversion of saltwater in our oceans to freshwater in our rivers
e) I do not know.

ECNR4. Which of these gases is NOT a greenhouse gas?

a) Argon b) Methane c) Nitrous oxide d) Ozone e) I do not know.

ECNR5. Most people know that hybrids use electricity to achieve good gas mileage and have emerged as a bridge between the benefits and limitations of both electric and gasoline powertrains. The hybrid is an innovative system for the environment because it produces:

a) zero greenhouse gas emissions.
b) low greenhouse gas emissions.
c) medium greenhouse gas emissions.
d) high greenhouse gas emissions.
e) I do not know.

ECE1. What form of energy is released from coal when it is burnt?

a) Heat energy from wind energy
b) Chemical energy from solar energy
c) Chemical energy from stored heat energy
d) Heat energy from stored chemical energy
e) I do not know.

ECE2. Which of the statements on energy transformation below is not correct?

a) Riding a bike: Gravitational potential energy → Kinetic energy + heat energy
b) Wood burning in a fire: Chemical energy → heat energy + light energy
c) A wind-up toy car travelling across the floor: Chemical energy → kinetic energy + heat energy
d) Running a solar-powered fan: Light energy → electrical energy + kinetic energy + heat energy
e) I do not know.

ECE3. The original source of energy for almost all living thing is:

a) The sun b) Water c) The soil d) Plants e) I do not know.

ECE4. Which of the following is NOT renewable energy?

a) Wind energy
b) Hydrogen energy
c) Solar energy
d) Fossil energy
e) I do not know.

ECE5. Solar panels on a house roof convert:

a) sunlight into steam which turns a turbine and a generator, making electricity.
b) sunlight into electricity directly.
c) sunlight into heat which turns a turbine and a generator, making electricity.
d) moonlight into electricity directly.
e) I do not know.

ECE6. Hydroelectric energy is energy derived from the movement of water. The energy is produced by:

a) falling water turning a turbine and generator.
b) hot water turning a turbine and generator.
c) hot water changing into steam which turns a turbine and generator.
d) falling water changing into steam which turns a turbine and generator.
e) I do not know.

ECE7. Which type of energy will be available for human use for the longest period of time?

a) Oil
b) Coal
c) Nuclear energy
d) Solar energy
e) I do not know.

ECE8-H. Which of the following is most likely to be an important worldwide source of energy for the future?

a) Solar radiation
b) Tidal flow
c) Geothermal sources
d) Wind power
e) I do not know.

ECB1. Ecology is the study of the relationship between:

a) different species of animals
b) plants and the atmosphere
c) organisms and their environments
d) humankind and the other animals
e) I do not know.

ECB2. Which of the following is a producer in an ecosystem?

a) Eucalyptus tree
b) Fungi
c) Human
d) Tiger
e) I do not know.

ECB3. There are many kinds of animals and plants, and they live in many different types of environments. What word is used to describe this idea?

a) Multiplicity
b) Biodiversity
c) Socioeconomics
d) Evolution
e) I do not know.

ECB4. Most of the oxygen in the atmosphere comes from:

a) Insects b) Plants c) The soil d) The sun e) I do not know.

ECB5. Some people started a program in a national forest to protect deer. They started killing wolves. Ten years later there were no wolves in the forest. For a few years after the wolves were gone there were many more deer than there had ever been. Then suddenly there were almost no deer. The people who wanted to protect the deer didn't know that:

a) deer only live to be a few years old
b) fires would kill so many deer
c) other animals would eat so much of the deer's food
d) the deer would eat all of the food then many would starve
e) I do not know.

ECB6. What happens immediately in an ecosystem if a producer can not use the energy from the sun?

a) The respiration of the producer will decrease.
b) Photosynthesis activity will stop.
c) The number of living things in the ecosystem will increase.
d) The decomposer in the ecosystem will cease to operate.
e) I do not know.

ECB7. If there were no decomposers on Earth, what would happen?

a) Dead plants and animals wouldn't become part of the soil.
b) Many human diseases would disappear.
c) More meat would be available for humans to eat.
d) Little would change.
e) I do not know.

ECB8-H. Features that help an animal survive are called:

a) Genetic diversity
b) Adaptations
c) Mutations
d) Skills
e) I do not know.

ECB9-H. When two or more species attempt to use the same limited resource in an ecosystem, their interaction is called:

a) Mutualism
b) Competition
c) Predation
d) Commensalism
e) I do not know.

ECB10-H. Biotic components are the living things that shape an ecosystem. which of the following is a biotic feature ?

a) Air temperature
b) Water level
c) Soil acidity
d) Predators
e) I do not know.

ECB11-H. A pollutant gets into an ecosystem and harms insects. How might this affect the ecosystem?

a) Plants are not harmed, so it doesn't affect the ecosystem.
b) It harms part of the ecosystem, so it may affect other parts of the ecosystem.
c) It kills insects, so other animals in the ecosystems stay healthy.
d) Most animals eat plants so it doesn't affect the ecosystem much.
e) I do not know.

ECB12-H. After living things die, they decompose. As a result of this process nutrients are:

a) recycled
b) destroyed
c) unavailable
d) evaporated
e) I do not know.

Section Two. Knowledge of environmental issues: Understanding environmental issues resulting from human interaction with the environment

EI1. What is an increase in the average global surface temperature called?

a) Global warming
b) Latitude
c) Greenhouse gas
d) Acidification
e) I do not know.

EI2. The burning of fossil fuels has increased the carbon dioxide content of the atmosphere. What is the most immediate effect that this increasing amount of carbon dioxide is likely to have on our planet?

a) Warmer climate
b) Cooler climate
c) Decreased relative humidity
d) Increased relative humidity
e) I do not know.

EI3. Waste thrown into bodies of water kills fish because the decaying waste:

a) adds carbon dioxide to water
b) gives off a bad smell
c) removes the food eaten by fish
d) uses up oxygen needed by fishes in respiration
e) I do not know.

EI4. Which of the following is the cause of the 'greenhouse effect'?

a) Increased amount of carbon dioxide in the atmosphere that traps the heat radiated from the ground
b) Increased vegetation on the surface of the earth
c) Increased rate of melting of polar ice caps due to increased temperature of the atmosphere

d) Increased destruction of the ozone layer
e) I do not know.

EI5. Which of these is a likely consequence of climate change?

a) Biodiversity will increase.
b) Sea-levels will decrease.
c) The atmosphere will become colder.
d) The atmosphere will become hotter.
e) I do not know.

EI6. Which action can have the greatest impact on reducing the threat of global warming?

a) Recycling
b) Reducing energy use
c) Composting
d) Planting a tree
e) I do not know.

EI7. Many people believe that the Earth's average temperature is changing. They say that one important cause of this change is:

a) using fuels like gasoline.
b) the sun is moving closer to the earth.
c) acid rain.
d) rising ocean levels.
e) I do not know.

EI8. Acid rain is a problem because:

a) it may harm plants by affecting their leaves and changing the soil they grow in.
b) it may break down the layer of ozone in the Earth's atmosphere.
c) people may have to stay indoors when it's raining.
d) it may cause a slow change in the Earth's temperature.
e) I do not know.

EI9. Which of the following would be most likely to cause soil pollution?

a) Putting too much fertilizer on lawns
b) Organic gardening
c) Letting dead plants becomes part of the soil
d) Cutting lawns so short that the grass dies
e) I do not know.

EI10. Deforestation is the conversion of forested areas to non-forest land for human use. What is deforestation responsible for?

a) The distortion of the rainfall
b) The destruction of habitats and food species for wildlife
c) The destruction of soil in the mountains due to erosion
d) All of the above.
e) I do not know.

EI11-H. The layer of ozone in the Earth's atmosphere has developed holes because:

a) Some kinds of air pollution break down ozone.
b) The sun's rays have become more powerful.
c) The Earth's average temperature is changing.
d) Acid rain is breaking down ozone.
e) I do not know.

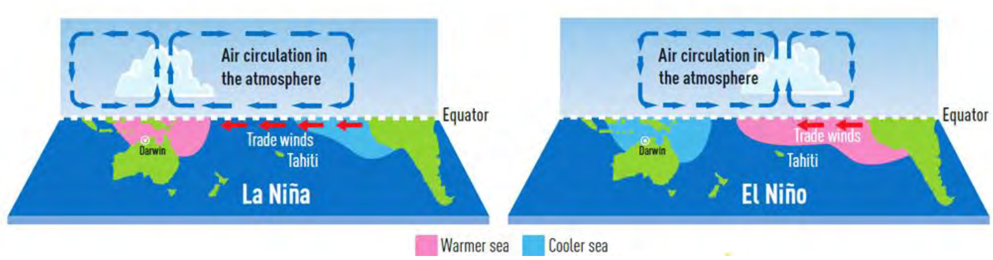
EI12-H. Why do people continue using energy sources that cannot be quickly replaced?

a) These energy sources are non-renewable.
b) The supply of energy is so large that it won't run out.
c) When these energy sources run out scientists will have others for people to use.
d) These energy sources are more convenient than other sources.
e) I do not know.

EI13-H. Carbon dioxide, methane, water vapour and nitrous oxide are examples of what?

a) Greenhouse gases
b) Major atmospheric components
c) Major gases found in car exhaust
d) Gases transpired by plants
e) I do not know.

EI14-H. **El Niño** events are associated with a warming of the central and eastern tropical Pacific, while **La Niña** events are the reverse, with a sustained cooling of these same areas. Which of the following statements is not correct?



a) La Niña occurs when trade winds are strong.
b) When El Niño occurs, the precipitation of the western Pacific Ocean increases.
c) The sea surface temperature measured in the eastern Pacific Ocean, such as off the coast of Peru, is higher when El Niño occurs.
d) The sea surface temperature of the western Pacific Ocean, such as of the coast of Australia, is higher when La Niña occurs.
e) I do not know.

ES1. Approximately 70% of all fresh water withdrawn for human use is used for:

a) Drinking
b) Cooking
c) Washing people and clothing
d) Irrigation
e) I do not know.

ES2. In the distillation of salt water into fresh water, heat is used to:

a) evaporate the salt from the water
b) evaporate the water from the salt
c) condense the salt from the water
d) condense the water from the salt
e) I do not know.

ES3. Conservation is a term used often when discussing the environment. We need to conserve energy. We need to conserve water. What does the word 'conserve' mean when used in this way?

a) Recycle and reject
b) Collect and recycle
c) Collect and protect
d) Save and protect
e) I do not know.

ES4. One energy source for humans is nuclear energy. However, people disagree with:

a) storing nuclear waste for thousands of years.
b) finding the materials needed to produce nuclear energy.
c) finding people to work in nuclear power plants.
d) changing nuclear energy into electricity.
e) I do not know.

ES5. The primary environmental benefit of a wetland is:

a) A place to grow wild rice
b) Filtering water
c) A hideout for ducks
d) Clean drinking water
e) I do not know.

ES6. The pollution of ocean water is a serious problem because:

a) ships have trouble travelling thought polluted water.
b) the oceans contain salt water.
c) ocean tides are affected.
d) oceans contain many kinds of plant and animal life.
e) I do not know.

ES7. How should humans best relate to nature?

a) Coexist with nature by understanding and protecting it
b) Wipe out all consumers that compete with humans and their animals
c) Increase food production with the use of irrigation, pesticides and inorganic fertilisers
d) Increase technological activities designed to control the environment
e) I do not know.

ES8. Hydroelectric power is beneficial to the environment because it uses the natural flow of water to turn large:

a) turbines
b) generators
c) dams
d) locks
e) I do not know.

ES9-H. One suggested advantage of using nuclear power plants instead of coal or oil for energy production is:

a) Nuclear power plants are not expensive to build.
b) The waste products are easy to store.
c) They are totally safe.
d) There is less air pollution.
e) I do not know.

ES10-H. Sustainable agriculture aims to:

a) produce enough food to sustain human society.
b) meet the demand for food at any costs.
c) produce enough food while maintaining stable economic costs.
d) meet the requirement for food while maintaining a healthy social, economic and ecological environment.
e) I do not know.

ES11-H. Extensive planting of trees to increase forest cover is called:

a) afforestation
b) agroforestry
c) deforestation
d) social forestry
e) I do not know.

Environmental Literacy Test Assessment (Questionnaire About Attitudes)

This section is questionnaire about the environmental attitude. There are no right or wrong answers. Read each statement below carefully and reflect on your experience in science class.

The strength of agreement is described as the range from 1 to 6. Decide the extent to which this statement describes your own attitude about the environment. If you absolutely agree regarding the statement, please mark an 'X' under '6'.

	Disagree ←				→ **Agree**	
	1	2	3	4	5	6
Humans have the right to rule over nature.						X

Please read each statement below and make an 'X' mark under the column you agree with the most for each statement.		**Disagree**	⟵		⟶		**Agree**
		1	**2**	**3**	**4**	**5**	**6**
NRN1	Humans have the right to rule over nature.						
NRN2	Living things in nature have the same right as humans to live.						
NRN3	Even though many technologies are advanced, humans are still under the laws of nature.						
NRN4	The earth has plenty of natural resources for humans.						
NRN5	The earth has a limited supply of space and resources.						
NEC1	If things continue the same way they are now, we will face a huge environmental disaster.						
NED2	The earth can support only a limited number of people.						
NEC3	Humans are really messing up the environment.						
NEC4	When humans change things in nature, it usually causes serious environmental problems.						
NEC5	Nature is easily pushed off balance.						
NHE1	Humans' problem-solving abilities will ensure that we can avoid ruining the earth.						
NHE2	Nature is strong enough to handle our modern lifestyle.						
NHE3	Humans will someday know enough about how nature works to be able to control it.						
NHE4	The 'environmental crisis' that many people talk about is not really a big problem.						
NHE5	When humans need things, we have the right to make changes to the natural environment.						
NHE6	To make the environment healthier, humans need to change their actions.						
DES1	It is important for people to think about the environment.						
DES2	I believe that I am sensitive to the environment.						
DES3	I want to encourage people to do something to protect the environment.						
DES4	I am not interested in the beauty of nature around me such as flowers, trees or clouds.						
DEC1	Predacious and wild animals such as snakes should not be killed because they also have right to live in ecosystem.						
DEC2	I get angry when I think about some companies that use animals for their own experiments						

DEC3	I am not concerned about a light on in an empty classroom at school because the school pays the electricity bill.						
DEC4	Global warming is largely a scare tactic by environmentalists.						
DER1	I can help the people working for the solution of environmental problem						
DEC2	I can change my lifestyle to protect natural resources.						
DER3	I would be willing to donate my allowance of $20 to an animal protection agency for endangered animals such as wolves and bears.						
DER4	The conservation of natural resources is totally the government's responsibility.						

NRN: NEP-right of nature, NEC: NEP-Eco-crisis, NHE: NEP-human exemptionalism, DES: Disposition-Environmental sensitivity, DEC: Disposition-Environmental concern, DER: Disposition-Environmental responsibility

Environmental Literacy Test Assessment (Interview)

The following interview questionnaire is selected from the list of environmental attitude questions. You will be interviewed based on these attitude questions and the interview will be recorded.

Interview Question 1

Do you agree that humans are really messing up the environment? Explain your response.

Interview Question 2

What do you think about the 'environmental crisis'? Is it a big problem?

Interview Question 3

Do you want to help people who are working to solve environmental problems? Explain your response.

Thank you very much for your co-operation in completing this questionnaire!

APPENDIX II: The frequency of correct answers in the EK scale on the ELTSQ

Sub-Category	Question no.	Year 7-8 (n=146)		Question no.	Year 9-10 (n=233)	
		No. Correct answer	Mean percentage		No. Correct answer	Mean percentage
Ecological knowledge - Nature resources	ECNR1.	53	36%	ECNR1.	132	57%
	ECNR2.	63	43%	ECNR2.	164	70%
	ECNR3.	56	38%	ECNR3.	134	58%
	ECNR4.	28	19%	ECNR4.	59	25%
	ECNR5.	41	28%	ECNR5.	142	61%
Ecological knowledge - Energy	ECE1.	49	34%	ECE1.	126	54%
	ECE2.	8	5%	ECE2.	31	13%
	ECE3.	74	51%	ECE3.	127	55%
	ECE4.	83	57%	ECE4.	191	82%
	ECE5.	62	42%	ECE5.	134	58%
	ECE6.	44	30%	ECE6.	106	45%
	ECE7.	94	64%	ECE7.	200	86%
				ECE8-H	137	59%
Ecological knowledge - Biodiversity	ECB1.	35	24%	ECB1.	114	49%
	ECB2.	67	46%	ECB2.	120	52%
	ECB3.	83	57%	ECB3.	179	77%
	ECB4.	95	65%	ECB4.	192	82%
	ECB5.	90	62%	ECB5.	159	68%
	ECB6.	73	50%	BCB6.	156	67%
	ECB7.	91	62%	BCB7.	172	74%
				BCB8-H.	123	53%
				BCB9-H.	143	61%
				BCB10-H.	23	10%
				BCB11-H.	168	72%
				BCB12-H.	169	73%
Environmental problems	EI1	111	76%	EI1	191	82%
	EI2	73	50%	EI2	184	79%
	EI3	20	14%	EI3	38	16%
	EI4	37	25%	EI4	112	48%
	EI5	64	44%	EI5	142	61%
	EI6	39	27%	EI6	105	45%
	EI7	52	36%	EI7	87	37%
	EI8	83	57%	EI8	172	74%
	EI9	98	67%	EI9	185	79%
	EI10	28	19%	EI10	49	21%
				EI11-H	132	57%
				EI12-H	157	67%
				EI13-H	90	39%
				EI14-H	24	10%
Environmental sustainability	ES1	23	16%	ES1	84	36%
	ES2	28	19%	ES2	80	34%
	ES3	51	35%	ES3	125	54%
	ES4	48	33%	ES4	123	53%
	ES5	39	27%	ES5	120	52%
	ES6	78	53%	ES6	160	69%
	ES7	76	52%	ES7	162	70%
	ES8	48	33%	ES8	90	39%
				ES9-H	105	45%
				ES10-H	120	52%
				ES11-H	97	42%

APPENDIX III: The frequency of positive responses in the EA scale on the ELTSQ

Sub-scale	Subscription	Question no.	No. answers (7-8) N=146			No. answers (9-10) N=233		
			Agree (5-6)	Neutral (3-4)	Disagree (1-2)	Agree (5-6)	Neutral (3-4)	Disagree (1-2)
NEP	Right of Nature: NRN	NRN2	75 (53)	53 (37)	15 (11)	115 (53)	83 (38)	22 (10)
		NRN3	45 (32)	66 (46)	32 (23)	84 (39)	115 (53)	20 (9)
		NRN4	75 (53)	57 (40)	11 (8)	118 (54)	72 (33)	30 (14)
		NRN5	101 (71)	37 (26)	6 (4)	163 (75)	51 (23)	5 (2)
	Eco-Crisis: NEC	NEC1	109 (78)	31 (22)	4 (3)	179 (82)	35 (16)	4 (2)
		NEC2	39 (28)	58 (41)	46 (33)	69 (32)	72 (33)	79 (36)
		NEC3	121 (86)	19 (14)	3 (2)	179 (82)	38 (18)	3 (1)
		NEC4	116 (83)	23 (16)	4 (3)	176 (81)	40 (18)	4 (2)
		NEC5	85 (61)	50 (36)	8 (6)	114 (53)	90 (41)	15 (7)
	Human exemptionalism: NHE	NHE1*	9 (6)	66 (47)	68 (48)	28 (13)	106 (50)	86 (40)
		NHE2*	53 (38)	66 (47)	25 (18)	102 (48)	85 (40)	32 (15)
		NHE3*	22 (16)	71 (50)	50 (35)	50 (23)	114 (53)	54 (25)
		NHE4*	94 (67)	31 (22)	17 (12)	165 (77)	35 (16)	18 (8)
		NHE5*	53 (38)	55 (39)	35 (25)	87 (41)	95 (44)	35 (16)
		NHE6	100 (71)	40 (28)	3 (2)	157 (73)	56 (26)	3 (1)
Disposition	Environmental sensitivity: DES	DES1	108 (77)	32 (23)	2 (1)	173 (79)	40 (18)	5 (2)
		DES2	56 (40)	67 (48)	18 (13)	79 (36)	119 (55)	20 (9)
		DES3	66 (47)	67 (48)	10 (7)	97 (44)	102 (47)	19 (9)
	Environmental concern: DEC	DEC1	96 (67)	44 (31)	3 (2)	110 (51)	88 (41)	20 (9)
		DEC2	66 (46)	67 (47)	10 (7)	89 (41)	100 (46)	28 (13)
	Environmental responsibility: DER	DER1	71 (50)	63 (45)	8 (6)	112 (51)	92 (42)	14 (6)
		DER2	61 (43)	76 (54)	5 (4)	101 (46)	101 (46)	16 (7)
		DER3	81 (57)	50 (35)	12 (9)	121 (56)	80 (37)	17 (8)

Appendix IV (page 103) removed from Open Access version as they may contain sensitive/confidential content.

Appendix V (pages 104-107) removed from Open Access version as they may contain sensitive/confidential content.