

RESEARCH ARTICLE

Exploration of Core Competencies from Delphi Survey and Design of Their Measurement Tools and Teaching & Learning Programs for Environmental Education in Elementary Schools

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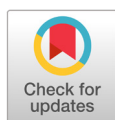
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ABSTRACT

This study aims to establish core competencies for environmental education in elementary schools, develop its measurement tools, and explore program grouping methods. To address these goals, three research questions were posed: identifying core competency elements, determining their assessment tools, and exploring the best ways to organize environmental education programs to develop the core competencies. Using a Delphi survey and literature review, the research pinpointed core elements such as 'autonomy', 'reflective ability', 'environmental sensitivity', and 'critical thinking ability', among others. Based on these competencies, 34 assessment items were devised. To enhance these competencies, a 'theme integration method' was proposed, intertwining environmental education with other curriculum topics. The study emphasizes the importance of an integrated approach, ensuring students grasp environmental subjects while achieving other learning objectives. Consequently, the measurement tools and learning & teaching programs for environmental education in elementary schools presented in this study assist teachers in customizing environmental topics based on regional, school, and individual teaching goals, rooted in the intended core competencies.

Key words: Core competencies, environmental education, assessment tools, assessment items, theme integration method

Introduction

Han (2016) described the Fourth Industrial Revolution as a socio-structural revolution led by cyber-physical systems in production, resulting from the advancement of cutting-edge technologies such as artificial intelligence and big data into convergent technologies of biotechnology, information technology, and cognitive science. Then, what kind of education is needed in the era of the Fourth Industrial Revolution? Han & Baek (2007) argued that in the knowledge-based society characteristic of the Fourth Industrial Revolution, public education should teach practical knowledge necessary for individuals to achieve self-realization while enhancing their capabilities, that is, the ability to lead a successful personal life while performing their given roles as members of society. On the other hand, Kim (2022) stated that even in the crisis situation of the coronavirus pandemic, cultivating core competencies such as communication skills, creativity, humanity, expertise, and globalization capabilities is essential for the future education of university students.

In response to these social trends and the need for change in the field of education, the OECD (Organization for Economic Co-operation and Development) in 2003 clarified the necessity of core competencies and the meaning and elements of these competencies as one of the strategies through which education can help students adapt successfully to changes in future society. Rychen & Salganik (2004), So (2007), Lee & Song (2007), and others have described core competencies as skills necessary for all individuals to lead successful lives and for society to sustainably maintain its functions well.

Yoon et al. (2007) conducted research on establishing standards and areas of core competencies in primary and secondary education curricula, and Lee et al. (2009), Kim et al. (2012), Lee et al. (2012), among others, provided insights into the design of primary and secondary education curricula based on these core competencies. The 2015 curriculum incorporated core competencies in each subject based on their characteristics, but the revised 2022 curriculum set a direction for the curriculum development towards nurturing proactive individuals equipped with inclusivity and creativity, thereby establishing a framework for core competencies. Compared to the 2015 revised curriculum, it can be observed that the communication competency, one of the core competencies, evolved into a broader collaborative communication competency, and although emphasis was placed on linguistic, mathematical, and digital literacy, the portion of core competency education specific to each subject seemed to be reduced. Above all, finding concrete evidence on how these core competencies have been utilized and taught in actual curriculum development and education, as well as understanding why core competency education is necessary and important in environmental education, remains a challenging task.

As a result, studies have been conducted on ways to develop core competencies in individual subject curricula and in actual classroom teaching. Park (2014) researched methods for fostering core competencies in elementary school English, while Yu (2016) did so for moral education curricula. Lee & Kim (2014) proposed a specific model for nurturing core competencies in elementary social studies classes, Kang & Lee (2016) presented teaching strategies for fostering core competencies and character in elementary art classes, and Jo (2017) offered strategies for cultivating core competencies in elementary physical education.

However, studies by Han & Baek (2007), Choi et al. (2011), Kwak (2012), Kim (2016), and others have suggested

that rather than being confined to the frameworks distinguished by subjects, it is more effective to integrate multiple subjects or learn in a cross-curricular manner to cultivate core competencies. These studies describe that if students acquire core competencies at school, they should be able to apply them in similar situations. The real-life scenarios that learners will face are different from the segmented learning situations divided by subjects, and to foster competencies, they proposed the need for cross-curricular thematic learning rather than learning individual knowledge divided by subjects. Generally, thematic learning targets content based on learners' interests or events actually occurring in the society they live in. In this context, one of the important issues and topics that emerge relating to the present and future society in which learners live is environmental education. The National Information Society Agency (2010) collected data on the future prospects of Korean society and megatrends, classifying them by social, technological, economic, environmental, and political categories, and ultimately selected major megatrends. Among them, in the environmental field, three critical topics were identified: climate change and environmental pollution, the energy crisis, and side effects due to technological advancements.

The 2015 curriculum presented by the National Curriculum Information Center (2015), specifically in the section on middle school education, describes the core competencies needed in environmental subjects, based on the core competencies suggested by the OECD and previous studies. Also, Seo & Johanes (2013) described why core competencies are important in middle school environmental education, Seo & Ryu (2014) suggested the direction that future environmental education should take, and Seo (2014) and Seo et al. (2020) identified the core competencies needed in middle school environmental education.

Furthermore, Wanchana et al. (2020) encouraged knowledge about the environment, basic understanding of the environment, responsibility for environmental education among specialist teachers, planning and implementation of environmental education, learning about and evaluation of environmental education as competencies for middle school teachers in environmental education. They argued that approaches for enhancing environmental education competencies should include multidisciplinary teaching and learning, community-based learning, project-based learning, joyful teaching and learning, and holistic learning management. However, there is still a lack of research on specific strategies and detailed discussions for nurturing the key elements of core competencies in environmental education within actual classroom settings. Particularly, there is a need to more concretely present the necessity of core competency education derived from elementary education.

Lee & Kim(2013) argued that environmental education can be conducted in elementary schools by including environmental content in subjects like social studies, science, and practical arts, and through 204-272 hours of creative experiential activities annually. However, according to a survey by the Minister of Environment(2009), the effectiveness of school environmental education is low because it is conducted in a one-time, discontinuous manner. Another survey by the Minister of Environment(2013) showed that many experts responded that school education is necessary as a desirable form of environmental education, and the general public also responded that environmental education in schools is necessary, following mass media.

In addition, many studies on elementary environmental education have described the need for it (Lee, 2013; Park, 2011; Yang, 2007), and while there were numerous environmental education programs targeting specific topics or

dispositions, there was virtually no research on education programs based on environmental competencies.

Internationally, there is an expanding trend of education about the environment and sustainability, starting from elementary schools, based on the need for such education. According to a report on the 'Future Focus', a key principle of the New Zealand curriculum, content related to sustainability concerning the future is best understood through elementary school environmental programs (Lee et al., 2013). Also, looking at the case of science subjects in Finland's core competency research trends, it was revealed that the curriculum was revised to study 'environment and natural science,' an integrated subject, throughout all grades of elementary school in response to the demand for convergent competency education (Chae & Noh, 2015).

These insights suggest a significant shift towards recognizing the importance of continuous, integrated environmental education from an early age, and a global trend of adapting educational curriculums to include environmental and sustainability education in response to future societal needs. However, there seems to be a gap in research and practice in effectively implementing competency-based environmental education programs, indicating an area that requires further research and development.

Currently, while the importance of core competencies in the educational curriculum is recognized, there is a lack of research on effective methods of implementing these competencies in actual educational settings. Particularly at the elementary school level, environmental education plays a crucial role in shaping students' awareness, attitudes, and behaviors towards the environment, necessitating a systematic cultivation of key core competencies. Additionally, developing tools to measure the effects of core competencies and creating effective core competency-centered educational models are imperative.

Therefore, the purpose of this study is to identify the essential core competencies needed in the environmental education curriculum at the elementary school level through Delphi surveys, to explore measurement tools for evaluating these competencies, and to introduce specialized teaching & learning programs aimed at the acquisition of core competencies for environmental education in elementary school.

Research Methods

Participants

In this study, questionnaires created for the Delphi survey were sent out to experts in two rounds via email, after which their opinions were collected. The criteria for selecting experts were based on whether they had majored in environmental education or were currently researching in the field. A total of 25 participants were selected and categorized into three groups: 19 active field teachers who majored in environmental education, 3 graduate students, and 3 undergraduate students majoring in environmental education (Table 1). The response rates for the Delphi questionnaires were 25 participants (100%) for the first survey and 20 participants (80%) for the second survey.

Table 1. Characteristics and the number of participants for the Delphi Survey

Classification	Characteristics	Number of participants in Delphi survey
Teachers	Active professionals who majored in environmental education, possessing field experience and an understanding of the essence of the current educational curriculum	19
Graduate Students	Individuals who have majored in or are researching environmental education, capable of providing key competencies necessary for the nature and content of environmental education	3
Undergraduate Students	Individuals who have majored in environmental education and have learning experience related to the current educational curriculum	3

Procedure

Table 2 represents the key competency areas, sub-elements, and related meanings in the elementary school environmental education curriculum for the Delphi survey.

In the Delphi survey, the Content Validity Ratio (CVR) serves as a crucial indicator for assessing the validity of the surveyed content. Specifically, CVR is used as a measure of the necessity of items evaluated by an expert panel. This ratio numerically represents how appropriate specific survey items or questionnaire questions are to the research topic or objective (Seo, 2014). According to Lawsche (1975), content validity is satisfactory if the CVR value lies between 0 and 1 when the number of expert panelists who have responded that the content of the survey question is valid is between 50% and 100%. At this time, the Content Validity Ratio $CVR = [N_e - \frac{N}{2}] / [\frac{N}{2}]$. Here, N is the total number of responses, and N_e is the number of panelists who responded as valid. In this study, the term refers to the combined frequency of experts who responded with 4 (appropriate) or 5 (very appropriate) on the 5-point Likert scale used.

According to Lawsche (1975), the CVR value varies depending on the number of expert panels participating in the Delphi survey. It was suggested that items with a CVR of 0.49 or higher when there are 15 panelists, 0.42 or higher when there are 20, 0.37 or higher when there are 25, and 0.33 or higher when there are 30, have content validity. In this study, there were 25 experts in the first round and 20 in the second, so based on Lawsche (1975)'s research, it was determined that items with a CVR of 0.37 or higher in the first round and 0.42 or higher in the second round have content validity.

In Delphi surveys, another method to verify the validity presented by expert panels is by checking the degree of consensus and convergence. The degree of consensus and convergence allows us to understand to what extent the expert panels agree on opinions. According to Lee (2001), the formulas for calculating the degree of consensus and convergence are as follows: Degree of Consensus = $1 - \frac{Q_3 - Q_1}{Mdn}$, Convergence = $\frac{Q_3 - Q_1}{2}$. In these formulas, Mdn represents the median, while Q_1 and Q_3 signify the first and third quartiles, respectively. A larger difference between the values of and indicates a lower degree of consensus and a higher degree of convergence.

According to Sea (2014), if the value of the degree of consensus is 0.75 or higher, it is considered that there is a fair amount of agreement among the expert panels. Also, a convergence value within the range of 0 to 0.5 was viewed as a positive outcome. Therefore, in this study, it was determined that an item possesses validity when the degree of consensus among the responding expert panels is 0.75 or higher, and the degree of convergence has a value within the range of 0 to 0.50.

Data Collect and Analysis

The data collected through the first and second Delphi surveys in <Table 3> were analyzed using MS-Excel 2014 and SPSS 17.0 statistical programs. Descriptive statistics (mean, standard deviation, median, interquartile range, etc.), CVR values, degrees of consensus, and convergence from the expert panels were calculated.

In addition to these, the affirmation rate was used as a criterion for judging the validity of items. This refers to the response rate of 4 points (appropriate or valid) or higher on a 5-point Likert scale. In this study, following the research by Tigelaar et al. (2004) and Seo (2014), an affirmation rate of 0.75 or higher was set, considering it as securing validity for the items if the rate is 75% or higher.

Based on prior studies, this research adopted the environmental competencies proposed by the North American Association for Environmental Education (2011) as a major premise. It organized four main areas and twelve key competency elements necessary for nurturing these competencies in elementary schools. Relying on the studies by Seo (2014) and Seo et al. (2020) concerning essential competencies required in middle school environmental studies, the research selected key competency elements demanded in elementary schools. This selection was made from the competencies outlined in the current overview of middle school environmental studies and those needed in the 'environmental' mega-trends presented in the research by Lee et al. (2012) and Lee & Song (2007). These elements were listed in Table 2. Based on this, the survey questions were created concerning the necessity of individual key competency elements, the appropriateness within the specific area, and the adequacy of the definitions of individual competency elements.

Table 2. Areas, facets and meanings of core competency in environmental education for Delphi survey

Areas of core competency	Facets of core competency	Meanings of core competency
Personality- oriented area	Autonomy	Self-control ability to independently create and explain plans or rules within range that assert their own rights and that voluntarily abide by the rights of others (nature and others)
	Reflection- insight ability	As forming one's own perspective on the world, the ability to continuously and intentionally think deeply, evaluate and correct one's own thoughts and actions consistent with the principles of oneself, others, and nature
	Environment sensibility	The ability to inspire emotion while empathizing with the beauty or pain of the environment or react sensitively to changes in them
Thought - oriented area	Critical thinking skills	Ability to examine whether any arguments or data are based on reasonable grounds, rather than fragmented and passively accepted, and to evaluate suitability and validity
	Creativity	Ability to create new environmentally sustainable outcomes with insights while integrating various information and knowledge on recognized issues
	Problem solving skills	Ability to devise effective alternatives by finding and using knowledge and information on the problem at hand, and to select and apply the best alternative to devise
Tool utilization area	Skills to use language, symbols, and text	The ability to effectively use spoken and written skills, calculations and other math skills in a variety of situations. Examples include reading comprehension, mathematical literacy, and numeracy.
	Skills to use knowledge and information	The ability to recognize new things and secure appropriate sources of information, including gathering knowledge and information in cyberspace. This includes the ability to evaluate the excellence, suitability and value of information and sources, and to systematize knowledge and information.
	Skills to use new technology	Ability to equip professional technology with diversification of information and communication technology and information access methods of technological innovation and progress
Relation ship - oriented area	Communication skills	Ability to exchange and share knowledge, opinions, and meanings to pursue, understand, and achieve common goals
	Conflict solving skills	Ability to prevent conflict problems in advance or to find and implement appropriate solutions in consideration of the needs and opinions of stakeholders in conflict when a conflict occurs
	Co operation ability	Ability to form and maintain good relationships with members of the global community and to fulfill their roles and responsibilities by cooperating together

Results and Discussion

Essential core competencies needed in the environmental education curriculum at the elementary school level through 1st and 2nd Delphi survey

Validity Analysis on the Need of Facets of Core Competency

Based on the results of the first Delphi survey, among the core competency elements for elementary school environmental education, both 'skills to use language, symbols, and texts' and 'skills to utilize new technologies' scored low in terms of average scores, convergence, and CVR. This could indicate that the experts did not consider these two competencies as crucial in the context of elementary school environmental education. Moreover, feedback indicated that the definitions of these items were not appropriate, prompting the researchers to eliminate these competencies and rename the more encompassing and critical competency as 'skills to use knowledge and information'. This revised competency was included in the 'thinking-oriented area'.

Furthermore, more than half of the respondents suggested the inclusion of 'personal and social responsibility,' 'citizenship,' and 'environmental community consciousness' as core competency elements in environmental education. These responses emphasize the importance of individual responsibility, community awareness, and the role as citizens in environmental education. Consequently, the researchers incorporated these suggestions, adding new core competency elements.

Additionally, the 'cooperative skills' item was restructured due to its overlapping or ambiguous meaning, consolidating it into a unified core element called 'Environmental community awareness and citizenship'. These revisions and restructurings are expected to provide clearer and more focused competency development in environmental education programs at the elementary schools.

The results of the first and second Delphi surveys on the necessity of core competencies for environmental education in elementary schools are presented in <Table 3>. The second Delphi survey was conducted based on ten core competency elements including 'autonomy', 'reflection & insight ability', 'environmental sensitivity', 'critical thinking skills', 'creativity', 'problem-solving skills', 'skills to use knowledge and information', 'communication skills', 'conflict solving skills', and 'environmental community awareness and citizenship'. Twenty expert panelists participated in this survey. In the second Delphi survey, the response to the necessity of core competencies all showed an average of 4.00 or higher, indicating a strong agreement on their importance. The positivity rate was high, with all elements except for 'creativity' (85%) and 'autonomy' (95%) scoring 100%, highlighting unanimous or near-unanimous agreement on their relevance and necessity. The degree of agreement, represented by the agreement index, was shown in above 0.78 for all core competency elements, indicating a strong consensus among the experts. The degree of convergence, represented by the range between the lower and upper quartiles, showed a range of 0.00 to 0.50, suggesting a substantial level of agreement or convergence in opinions among the experts. Furthermore, the individual CVR values for the necessity of the ten core competencies were within the range of 0.70 to 1.00, indicating that the validity of these competencies was well-established and recognized by the panel of experts. This suggests that these core competencies are considered highly relevant and crucial for environmental education in elementary schools.

Table 3. The validity analysis of 1st and 2nd Delphi survey on the need of facets of core competency for environmental education in elementary schools

Facets of core competency	1st Delphi survey				2nd Delphi survey			
	Positivity rate (%)	Degree of agreement	Degree of convergence	CVR	Positivity rate (%)	Degree of agreement	Degree of convergence	CVR
Autonomy	84	0.75	0.50	0.68	95	0.78	0.50	0.90
Reflection & insight ability	96	0.80	0.50	0.92	100	1.00	0.00	1.00
Environment sensibility	96	1.00	0.00	0.92	100	1.00	0.00	1.00
Critical thinking skills	92	0.80	0.50	0.84	100	1.00	0.00	1.00
Creativity	84	0.75	0.50	0.68	85	0.80	0.50	0.70
Problem solving skills	88	0.80	0.50	0.76	100	0.85	0.38	1.00
Skills to use language, symbols, and text	60	0.63	0.75	0.20	-	-	-	-
Skills to use knowledge and information	80	0.75	0.50	0.60	100	0.78	0.50	1.00
Skills to use new technology	68	0.50	1.00	0.36	-	-	-	-
Communication skills	96	0.80	0.50	0.92	100	1.00	0.00	1.00
Conflict solving skills	92	0.80	0.50	0.84	100	0.80	0.50	1.00
Cooperative skills	96	0.90	0.25	0.92	-	-	-	-
Environmental community awareness and citizenship	-	-	-	-	100	1.00	0.00	1.00

Validity Analysis on Areas of Core Competency

In the second Delphi survey, the competency elements 'skills to use language, symbols, and texts', 'skills to use new technologies', and the area 'Cooperative skills' were omitted from the first Delphi survey. Consequently, the survey analyzed the appropriateness of the distinctions and definitions of the three areas: 'personality-oriented area', 'thinking-oriented area', and 'relationship-oriented area'.

All three areas had averages exceeding 4.20, and the positivity rates were above 90%, indicating strong agreement on their significance and appropriateness among the participants. The degree of agreement was above 0.75 for all areas, signifying a strong consensus. The degree of convergence was within the range of 0.00 to 0.05, suggesting a high level of agreement among the expert panelists' opinions. The CVR values, based on the responses from the 20 expert panelists, were above 0.70, meeting the threshold of 0.42, which reaffirms the validity of all three areas. Therefore, it was concluded that all three areas have established their validity (Table 4).

Table 4. The validity analysis of the 2nd Delphi survey on area of core competencies

Area of core competency	Mean	Standard deviation	Positivity rate (%)	Degree of agreement	Degree of convergence	CVR
Personality-oriented area	4.20	1.15	90	0.75	0.50	0.80
Thinking-oriented area	4.50	1.19	90	0.85	0.38	0.80
Relationship-oriented area	4.40	1.14	95	0.80	0.50	0.90

In response to the narrative feedback, changes were made to the definitions within the areas to reflect clearer and more appropriate terminology, especially considering the context of elementary school students. In the 'personality-oriented area', the term "preferences" was perceived as vague, leading to its replacement with "attitudes" to provide clearer meaning. For the 'thinking-oriented area', there was a request for terminology adjustments to reflect meanings more suitable for elementary students. Therefore, "a critical perspective" was changed to "a rational perspective" in the area definition, to be more fitting. Additionally, recognizing that solutions to problems are often "discovered" rather than "invented," the term "creation" was replaced with "exploration." In the 'relationship-oriented area', the term "rationally" was added to describe the approach to conflict resolution, enhancing the clarity of the methods used. Also, for consistency and to encapsulate a broader sense of coexistence, the term "others" was expanded to "others (humans and

nature)," shifting the focus from interpersonal to include the natural world as well (see Table 8).

Validity Analysis on Areas and Facets of Core Competency

The validity of the key competency elements per area was analyzed to determine whether they were appropriately set in each area. In the second Delphi survey, the key competency elements were as follows: First, in the personality-oriented area, 'autonomy', 'reflection & insight abilities', and 'environmental sensitivity' were included. Second, in the thinking-oriented area, 'critical thinking skills', 'creativity', 'problem-solving skills', and 'skills to use knowledge and information' were incorporated. Third, in the relationship-oriented area, 'communication skills', 'conflict solving skills', and 'environmental community awareness and citizenship' were involved. All ten key competency elements showed an average rating of 4.50 or higher, and the positivity rate was over 90%, indicating strong agreement among participants. The degree of agreement was also positive, with all elements scoring above 0.75, and convergence within the range of 0.00 to 0.05, suggesting a generally positive reception. The CVR exceeded 0.80 for all items, surpassing the minimum threshold of 0.42, with assessments from a panel of 20 experts. Therefore, it can be seen that the three areas have all secured validity (see Table 5).

Table 5. The validity analysis of 1st and 2nd Delphi survey on the area and facets of core competency for environmental education in elementary schools

Area	Facets of core competency	1st Delphi survey				2nd Delphi survey			
		Positivity rate(%)	Degree of agreement	Degree of convergence	CVR	Positivity rate(%)	Degree of agreement	Degree of convergence	CVR
Personality-oriented area	Autonomy	92	0.80	0.50	0.84	95	0.80	0.50	0.90
	Reflection-insight ability	92	0.80	0.50	0.84	100	0.80	0.50	1.00
	Environment sensibility	100	0.90	0.25	1.00	100	1.00	0.00	1.00
Thinking-oriented area	Critical thinking skills	100	0.80	0.50	1.00	100	1.00	0.00	1.00
	Creativity	92	0.80	0.50	0.84	100	0.75	0.50	1.00
	Problem solving skills	96	0.80	0.50	0.92	95	0.80	0.50	0.90
	Skills to use language, symbols, and text	80	0.75	0.50	0.60	-	-	-	-
	Skills to use knowledge and information	96	0.80	0.50	0.92	100	0.75	0.50	1.00
Relationship-oriented area	Skills to use new technology	80	0.75	0.50	0.60	-	-	-	-
	Communication skills	100	1.00	0.00	1.00	95	0.85	0.38	0.90
	Conflict solving skills	92	0.90	0.25	0.84	95	0.80	0.50	0.90
	Cooperative skills	96	0.80	0.50	0.92	-	-	-	-
	Environmental community awareness and citizenship	-	-	-	-	90	0.80	0.50	0.80

Validity Analysis on Definition of Facets of Core Competency

The results of the first and second Delphi surveys on the definitions of each item of the key competency elements were not presented in this content, but a comparison of the positivity rate, the degree of agreement, the degree of convergence, and CVR showed that the validity of most definitions of key competency elements was nearly 100%, close to 1, and the range of 0.00 to 0.05, respectively, indicating a near-consensus among the panel of experts.

Regarding the descriptive opinions from the first and second Delphi surveys on the definitions of each key

competency element: 'Autonomy' was redefined to emphasize spontaneity and sustainability to avoid overlapping meanings with 'reflection and insight abilities', and its scope was clarified. For 'reflection & insight abilities', the term was changed to just 'reflection abilities' to make it more suitable in the context of elementary schools. The definition of 'environmental sensitivity' was made more concrete. 'Creativity' was redefined not only to encompass creative outputs but also to emphasize the creativity involved in processes. 'Problem-solving skills' were clarified to avoid overlapping with 'creativity'. For 'skills to use knowledge and information', the term 'explore' was removed, acknowledging that it is implied within 'use'. The definition of 'communication skills' was expanded beyond simple communication. 'Conflict solving skills' were removed as an element altogether, following opinions that it was similar to 'problem-solving skills' and could be taught alongside it, or was included within it. 'Environmental community awareness and citizenship' was described in a way that fits within the flow of the context without deviating from the definition of the relationship-oriented area (see Table 8).

Ranking of Core Competencies to Be Emphasized In Elementary School

In the Delphi surveys, experts ranked key competencies they believed to be most crucial in elementary environmental education. Their responses reflect a collective perception of certain key competencies being particularly important in this educational context.

According to the results of the second Delphi survey, the top-ranked key competencies are as follows: Environmental sensitivity (20.0%) is the ability of students to recognize their environment and understand how it affects them and other living beings. Community environmental awareness and citizenship (16.0%) is the awareness in students of how their actions can impact their local and broader environment, and the responsibility to act for a sustainable future. Communication skills (14.0%) is the ability for students to effectively convey their thoughts and feelings, and to learn and grow through interactions with others. Critical thinking (10.0%) is the ability to analyze and evaluate information for problem-solving and the generation of new ideas. Self-reflection (10.0%) is the ability to reflect on and understand one's own thoughts and actions, leading to personal growth and development.

These results indicate that a deep understanding and respect for the environment, and the essential competencies to play an active and meaningful role within it, are valued in elementary environmental education. These elements are central to equipping students to respond to future environmental challenges and lead changes for a sustainable world (refer to Table 6).

Table 6. Ranking of 1st and 2nd Delphi survey on facets of core competency for environmental education in elementary schools

Facet	Ranking of 1st Delphi survey					Ranking of 2nd Delphi survey				
	1	2	3	4	5	1	2	3	4	5
Core competencies (%)	Environment sensibility (18.8)	Cooperative skills (13.3)	Problem solving skills (11.7)	Communication skills (10.9)	Reflection & insight ability (7.8)	Environment sensibility (20.0)	Environmental community awareness and citizenship (15.0)	Communication skills (14.0)	Critical thinking skills (10.0)	Self-reflection (10.0)

vRanking of Core Competencies to Be Emphasized in Each Academic Year

The survey, allowing for multiple responses, revealed preferences for emphasizing certain core competencies at specific grade levels in elementary education. The findings suggested: 'Autonomy' should be a focus in the 3rd-4th grades (40%). 'Reflection & insight ability' should be emphasized in the 5th-6th grades (60.5%). 'Environmental sensitivity' is crucial in the 1st-2nd grades (58.2%). 'Critical thinking skills' are key in the 5th-6th grades (51.4%). 'Creativity' should be fostered in the 3rd-4th grades (39.6%). 'Problem solving skills' are vital in the 5th-6th grades (59.0%). 'Skills to use Knowledge and Information' is important in the 5th-6th grades (41.0%). 'Communication skills' should be developed in the 3rd-4th grades (42.0%). 'Conflict solving skills' are necessary in the 5th-6th grades (50.0%). A sense of 'environmental community awareness and citizenship' should be nurtured in the 5th-6th grades (45.1%).

However, some expert panelists argued that dividing competencies by grade level is less meaningful. They believed it's essential for all core competencies to be integrated consistently across all grades, tailored to each level. Continuous education is key. Particularly for 'environmental sensitivity', it was viewed as especially relevant to integrated subjects in the 1st-2nd grades. Experts suggested that expressing feelings or thoughts about nature could be done in various ways according to grade level across all grades (refer to Table 7).

Table 7. Core competencies for environmental education in each grade of elementary schools

Core competencies for environmental education	Academic year						Total
	1st	2nd	3rd	4th	5th	6th	
Autonomy	7.5	15.0	17.5	22.5	20.0	17.5	100.0
Reflection-insight ability	4.7	4.7	14.0	16.3	32.6	27.9	100.0
Environment sensibility	32.7	25.5	14.5	9.1	9.1	9.1	100.0
Critical thinking skills	0.0	0.0	24.3	24.3	21.6	29.7	100.0
Creativity	12.5	10.4	20.8	18.8	20.8	16.7	100.0
Problem solving skills	0.0	5.1	12.8	23.1	28.2	30.8	100.0
Skills to use knowledge and information	7.7	15.4	15.4	20.5	20.5	20.5	100.0
Communication skills	12.0	20.0	22.0	20.0	14.0	12.0	100.0
Conflict solving skills	2.5	5.0	17.5	25.0	27.5	22.5	100.0
Environmental community awareness and citizenship	11.8	11.8	15.7	15.7	23.5	21.6	100.0

Final Core Competencies to Be Developed in Environmental Education of Elementary School

The results of the first and second Delphi surveys were analyzed, and based on the feedback on the open-ended questions, the final three orientated areas (personality, thinking, relationships) and nine key competencies ('autonomy', 'reflection & insight', 'environmental sensitivity', 'critical thinking skills', 'creativity', 'problem-solving skills', 'skills to use knowledge and information', 'communication skills', 'environmental community awareness and citizenship') necessary in elementary environmental education were revised and are presented in Table 7. Consequently, this study employed the Delphi survey method, commonly used for reaching consensus among experts, and was conducted in two rounds. After the first and second surveys, the researchers analyzed the results, also considering feedback on open-ended questions which provided more detailed insights that might not be apparent from fixed-response questions. Based on this comprehensive feedback, they refined the framework for core competencies necessary in elementary environmental education.

The final framework consists of three primary oriented areas and nine key competencies. In the oriented areas, the personality area emphasizes the students' personal qualities and ethical considerations regarding the environment, focusing on the development of personal qualities and ethical concerns. The thinking area encourages students to think critically and innovatively about environmental issues, focusing on cognitive abilities. The relationships area emphasizes the importance of social skills and community awareness, teaching students to engage positively with others and their environment. In terms of key competencies, Autonomy encourages students to develop independence and self-direction, taking personal responsibility for their learning and actions concerning the environment. Reflection & Insight include the ability for deep thinking, self-awareness, and understanding complex environmental issues at a deeper level. Environmental sensitivity involves students developing an emotional connection to the environment and understanding the importance of the impact of their actions on the surrounding world. Critical thinking skills are essential for analyzing and evaluating issues to form reasoned judgments, especially regarding environmental challenges. Creativity emphasizes the ability to encourage innovative thinking and propose unique solutions to environmental issues. Problem-solving skills focus on addressing environmental problems and challenges. Skills to use knowledge and information involve students learning to find and effectively use information and knowledge, applying what they have learned to real-life environmental situations. Communication skills include effectively sharing ideas related to articulating and clearly conveying one's thoughts on environmental issues. Environmental community awareness and citizenship reinforce a sense of responsibility and active participation in community and environmental issues.

These oriented areas and key competencies are ultimately presented in Table 7. This framework assists educators in understanding what essential competencies are in elementary-level environmental education, helping them design curricula and teach classes that foster these important skills and qualities in students.

Comparing the core competencies derived for elementary school environmental education with those presented in the 2022 curriculum, it is evident that the personality-oriented area and thinking-oriented area (creative thinking competency) have been further specified and systematized in common. However, the relationship-oriented area differs in the 2022 revised curriculum, substituting the knowledge and information processing competency; while communication skills remain similar, there are differences in community awareness and civic education. The 2022 curriculum places more emphasis on basic literacies such as language, mathematics, and digital literacy. Particularly, to cultivate digital literacy, the instructional hours related to digital SW and AI have been increased, and the curriculum in subjects has been developed to utilize digital and AI in teaching, learning, and assessment. However, these competencies were excluded from the first round of the Delphi survey in this study. For this section, it would be necessary to include the tool utilization area from Table 1 in Table 8 when reflecting the contemporary demands of social changes such as digital transformation, climate and ecological environment changes, demographic shifts, the complexity and diversity of society, the need for customized education that supports individual student characteristics and career paths, and the trends towards curriculum autonomy and decentralization.

Table 8. Areas, facets and definition of core competency in environmental education of elementary school

Area Elements	Definition
Personality-oriented area	A group of competencies related to discovering and understanding one's own existence, attitudes, and values, and continuously developing them in a healthy way in the light of one's own and the other's point of view.
Autonomy	Self-control ability to independently create and explain plans or rules within range that assert their own rights and that voluntarily abide by the rights of others (nature and others)
Reflection & insight ability	As forming one's own perspective on the world, the ability to continuously and intentionally think deeply, evaluate and correct one's own thoughts and actions consistent with the principles of oneself, others, and nature
Environment sensibility	The ability to inspire emotion while empathizing with the beauty or pain of the environment or react sensitively to changes in them
Thinking-oriented area	Ability to understand various situations in an integrated way and to search for alternatives to problems by constructing knowledge with a rational perspective
Critical thinking skills	Ability to examine whether any arguments or data are based on reasonable grounds, rather than fragmented and passively accepted, and to evaluate suitability and validity
Creativity	Ability to create new environmentally sustainable outcomes with insights while integrating various information and knowledge on recognized issues
Problem solving skills	Ability to devise effective alternatives by finding and using knowledge and information on the problem at hand, and to select and apply the best alternative to devise
Skills to use knowledge and information	Ability to access and acquire various types of knowledge and information in various ways, evaluate and systematize their suitability and value
Relationship-oriented area	Ability to rationally resolve conflicts through communication with others and to live with others (humans and nature)
Communication skills	The ability to exchange knowledge, to present and understand one's opinions to others, and to listen to and respond appropriately to the opinions of others in order to pursue, understand, and achieve mutually agreed goals.
Environmental community awareness and citizenship	The ability to fulfill one's roles and responsibilities while forming an amicable relationship through social communication and participation required as a member of the global community based on environmentally sound knowledge, skills, values and attitudes

Exploration of Measurement Tools of Core Competency Factors for Environmental Education in Elementary school

The evaluation criteria for each competency, according to the three oriented areas and nine key competencies confirmed through the first and second Delphi surveys, have been finalized as shown in Table 9. The main criteria were organized based on the definitions of the key competencies, and evaluation criteria proposed in previous studies were extracted, then modified or deleted to suit the subjects and topics.

Table 9. Evaluation criteria by elements of determined core competencies

Area	Elements	Evaluation criteria
Personality -oriented area	Autonomy	Independent decision making
		Assertive self-expression
		Implementation of self-help behavior
	Reflection·insight ability	Self-exploration
		Self-understanding
		Searching others
	Environment sensibility	Understanding others
		Sensitivity
		Aesthetics and emotional stability
		Sympathy and compassion

Table 9. Evaluation criteria by elements of determined core competencies

Area	Elements	Evaluation criteria
Thinking -oriented area	Critical thinking skills	Checking the implicit assumptions
		Assess the validity of the evidence
		Consistency of the argument
	Creativity	Divergent thinking
		Convergent thinking
		Creative problem solving
	Problem solving skills	Outputs
		Clarification of problems
		Analysis of cause
		Development of alternatives
		Plan and execute
Relationship -oriented area	Skills to use of knowledge and information	Performance evaluation
		Search and access to knowledge and information
		Understanding and synthesis of knowledge and information
		Expression and delivery of knowledge and information
		Evaluation of knowledge and information
	Communication skills	Translation
		Goal setting
		Self-presentation
	Environmental cooperation ability and citizenship	Conversion of messages
		Sense of unity and mutual influence
		Common consciousness
		Social participation
		Community service

For 'autonomy,' the evaluation criteria were based on previous studies by Choi (2007) and Jeong (2014), considering autonomous decision-making, assertive self-expression, and self-helping behavior enactment. However, reflective self-assessment was excluded as it was deemed to overlap with reflective ability. The evaluation criteria for 'Reflective Ability' were chosen based on previous studies by Moon (2014), focusing on self-exploration, self-understanding, exploration of others, and understanding of others. Here, "others" and "nature" were combined into "others", hence the term in the evaluation criteria was changed from "others" to "others(nature and others)". The evaluation criteria for 'environmental sensitivity' were determined based on studies by Kang (2009) that align with the definition of 'environmental sensitivity' in this study. The criteria were set as sensitivity, aesthetic sense and emotional stability, and empathy and compassion. The evaluation criteria for 'critical thinking skills' were selected from James & Burton (2017)'s research, ensuring they were consistent with the definition of the competency in this study and did not overlap with other key competencies. The evaluation standards for 'creativity' were adopted from Sung & Sung (2016)'s research, which presented measurement tools for creativity in lessons. These were chosen because they encompass the meaning of 'creativity' as a key competency in this study and include creative aspects in the problem-solving process.

The evaluation criteria for 'problem-solving skills' were chosen from Lee et al. (2003)'s measurement tool for problem-solving abilities, which methodically presents a series of processes for solving problems, aligning with this study's focus on learning the process of problem-solving. The criteria for 'skills to use knowledge and information'

were adapted from Lee et al. (2012)'s research on information utilization skills, based on cases of school library use. The criteria's name was revised by adding the meaning of the knowledge already known by the individual to the information in the existing research. The evaluation criteria for 'communication skills' were selectively chosen from Lee et al. (2003)'s study, focusing on criteria that go beyond the meaning of elementary-level communication and emphasize communication and understanding with others. 'Environmental community awareness and citizenship' was challenging to find suitable examples from existing research where criteria for evaluating 'environmental community awareness' were presented. Therefore, only items fitting this study's definition were selectively chosen as evaluation criteria from among those for 'community awareness' and 'community citizenship.' The attributes were then restructured and presented based on the original sub-elements of the evaluation criteria from previous studies and the meanings of the terms.

Based on the nine key competency elements selected for elementary environmental education, measurement tools were developed as shown in <Table 10>. In this study, based on 34 items of evaluation criteria within the three oriented areas and nine key competency elements defined, measurement questions were developed. Here, the evaluation criteria and questions for the key competencies are not only measurement tools to assess the level of competency cultivation but can also be used as standards for organizing programs, selecting instructional content, and methods.

On the other hand, the number of core competency measurement items proposed in this study may be somewhat extensive for 5th and 6th grade elementary school students to administer. Additionally, the study does not present verification of the reliability and validity of the developed items. Future research should focus on applying the programs introduced in the next chapter directly into classroom settings, not only to adjust the number of measurement items but also to enhance their reliability and validity in the core competency measurement tool.

Table 10. Detailed items of the core competency measurement tool(cintinued)

Element	Measurement Tool	Measurement Item
Personality - Autonomy	Independent decision Making	I make decisions on my own for everything.
		I often act as others tell me to.
	Assertive self-expression	If I think something is right, I definitely push for it.
		I can easily tell others what I've decided without hesitation.
Personality - Reflection -insight ability	Implementation of self-help behavior	I often show my feelings and emotions to others.
		I often show my feelings and emotions to others.
		I willingly do difficult tasks if it means I can get what I want.
		Once I plan something, I definitely put it into action.
	Self-exploration	I always do my best to take responsibility for the tasks I've taken on.
		(When encountering environmental issues or topics) I try to find out in which situations I get irritated.
	Self-understanding	(When I encounter an environmental issue or topic) If I get angry, I think about why I'm angry.
		(While dealing with an environmental issue or topic) When I get angry, I reflect on why I acted the way I did.
	Searching others	(Regarding environmental issues) I understand the impact of my worries on me.
		(Regarding environmental issues) I often discover the meaning behind the experiences I go through.
Personality - Environment sensitivity	Understanding others	I think about the actions I took in unpleasant situations and realize fears I wasn't aware of.
		When I have a differing opinion with someone, I think about what they might want.
	Sensitivity	When I have a conflict with someone, I wonder what they think is the cause of the conflict.
		When I don't like someone, I reflect deeply on what might be going on between us.
	Aesthetics and emotional stability	By deeply understanding conflicts with others, I view them in a different light.
		When I reflect on someone's behavior, I emotionally understand their feelings.
	Sympathy and compassion	When there's a clash of opinions with someone, I think about what solution might be beneficial for both of us.
		I marvel at the changes in the environment (buds, flowers, fruits, leaves) I see with the change of seasons.
	Creative problem solving	When I see moving animals (insects and bugs), I'm fascinated and curious to learn more.
		The sound of birds in the forest sounds beautifully like music to me.
Thinking-Critical thinking skills	Checking the implicit assumptions	I feel the beauty when I see photos or paintings containing nature (like flowers, butterflies, trees, oceans, and forests).
		I feel joyful and happy when walking through the woods.
	Assess the validity of the evidence	I find going to the mountains or the sea more enjoyable and happier than going to an amusement park.
		When I touch animals or insects to observe them, I feel they might get hurt.
	Consistency of the argument	I get angry and sad when I see adults catching animals carelessly.
		I feel that trees by the roadside might suffer because of car fumes.
Thinking-Creativity	Divergent thinking	I can recognize what is being presupposed in statements or claims.
		I know what is not explicitly stated in arguments or claims but is considered essential from each perspective.
	Convergent thinking	I can find evidence to support my claims or thoughts.
		I can understand the appropriateness of evidence that can be presented from different perspectives.
	Creative problem solving	I can identify inconsistencies in arguments.
		I can identify inconsistencies in someone else's claims or statements after hearing them.
	Outputs	I can think of multiple ways to solve a problem.
		I can connect various thoughts together.
	Clarification of problems	I can use what I've learned to solve problems.
		I can identify illogical parts in the data.
Thinking-Problem solving skills	Creative problem solving	I can prepare evidence to support a claim.
		I can discern the similarities and differences between my thoughts and those of my friends.
	Outputs	I can identify and solve problems that others might overlook.
		I can evolve ordinary thoughts into creative solutions.
Thinking-Problem solving skills	Clarification of problems	I can create new and useful outcomes.
		I compare the difference between my ideal image and the current situation.
	Creative problem solving	I contemplate the outcome if a problem remains unsolved.
		I clearly know what problem I need to solve.

Table 10. Detailed items of the core competency measurement tool

Element	Measurement Tool	Measurement Item
Thinking-Problem solving skills	Analysis of cause	I collect information about similar situations to understand the cause of the issue I am pondering.
		I believe that every problem has a significant cause and I seek that cause.
		When a problem arises, I first think of the causes of problems I've experienced in the past.
	Development of alternatives	I relate various events and issues occurring in everyday life.
		I look at the problem from a completely different perspective than what I've considered before.
		I compare the methods I've thought of for solving the problem to see if they're novel and appropriate.
	Plan and execute	I detail out the tasks in sequence to achieve my goals.
		I consider the amount of time and resources available when planning to solve the problem.
		Although I cannot be certain of the outcome, if there's a possibility of success, I actually give it a try.
	Performance evaluation	I check whether the initial problem I aimed to solve has been resolved.
		Even if the results aren't good now, I look for better ways to improve in the future.
		I discuss with others about how the solution can be improved.
Thinking- Skills to use of knowledge and information	Search and access to knowledge and information	When looking for books or online materials, I review the preface, title, and table of contents.
		I can precisely understand what knowledge and information I'm searching for.
		I can independently search for the required knowledge and information using school or local library's internet.
	Understanding and synthesis of knowledge and information	Depending on the purpose of searching for knowledge and information, I can aptly skim or read the entirety.
		I can judge how much the information I've found helps in solving tasks.
		I can appropriately use books, newspapers, magazines, the internet, and E-books based on the assignment.
	Expression and delivery of knowledge and information	I can summarize the content I've heard or read briefly.
		I can organize knowledge or found information in charts, or explain and present solved tasks to friends.
		I can organize compiled data using computer programs (Hangul, PowerPoint, Prezi).
	Evaluation of knowledge and information	After solving a task, I reflect on my own process of problem-solving.
		I can compare my work with that of other students, identifying strengths and weaknesses.
		I am open to criticism from others based on learning outcomes.
Relationship-Communication skills	Translation	When my opinion and the other person's differ, I recognize the differences.
		I sometimes understand another person's mood by observing their facial expressions and gestures.
		I tell the other person how I perceive and understand their emotions and feelings.
	Goal setting	I think in advance about what I want to say and wait for the right opportunity to express it.
		To effectively convey my message, I not only use words but also actively use facial expressions and gestures.
		If I'm curious about something, I ask repeatedly until I get an accurate answer.
	Self-presentation	I honestly share my thoughts with the other person.
		I clearly speak about things I'm not familiar with.
		Instead of trying to hide my weaknesses, I seek advice from others.
	Conversion of messages	During conversations, I try to put myself in the other person's shoes.
		I converse while considering how the other person might perceive my words.
		I ensure the clarity of my message by asking the other person how they have understood my words.
Relationship-Environmental cooperation ability and citizenship	Sense of unity and mutual influence	Sometimes, I feel as if the wrongdoings of others in the community are my responsibility.
		When others in the community do well, I feel joy as if it were my own accomplishment.
		If someone in the community is in trouble, I help as if it's my own problem.
	Common consciousness	Even if no one is watching, I follow the rules of the community.
		I have a sense of ownership towards the community.
		I believe that participating in environmental protection movements is essential to being a good citizen.
	Social participation	When I become an adult, I plan to participate in various ways (expressing personal opinions, wearing ribbons or badges, attending non-violent rallies, signing petitions, boycotting certain products, using protest slogans/sprays/paintings on walls) against issues I perceive as wrong.
		I don't litter and pick up trash when I see it.
		Even if an activity in my community doesn't bring direct benefits to me, if it benefits my neighbors or colleagues, I'm willing to invest my time and money in that particular activity.

Introduction of Specialized Teaching & Learning Programs to Develop Core Competencies for Environmental Education in Elementary School

Selection of Themes for Environmental Education Programs

Integrating the content of the elementary environmental education textbook 'children's green world (2022)' for 5th and 6th graders with that of middle school environmental studies, and elaborating on the lesson content for the effective evaluation of the based measurement tools, is a crucial step. In this process, it's essential to precisely understand how various key competency elements are connected to each subject's achievement standards, and to deliver the content in a way that students can understand and apply.

The integration of educational content involves examining the 'children's green world' textbook and the content of middle school environmental studies to analyze how these two educational materials can complement each other and be interconnected. This helps students understand the continuity between elementary and middle school educational content. Setting achievement standards involves clarifying, based on the 2015 elementary school curriculum achievement standards, how each key competency is linked to specific achievement criteria in subjects. This enables teachers to understand how to integrate each key competency into the subject matter they teach. Programmization requires the specific design of educational programs so that students can actually cultivate key competencies. This can include various educational methods such as discussions, project-based learning, and field studies. Additionally, this program should also provide ways for students to self-assess their level of understanding. The development of evaluation methods involves creating various tools to assess students' learning processes and outcomes. This can include standardized tests, portfolios, self-assessments by students, and peer reviews. Through these methods, students can cultivate a deep understanding of the environment and develop the necessary competencies for a sustainable future.

In the analysis of environmental education content elements and achievement standards, science standards focused on the causes of climate change, social studies addressed efforts to solve environmental problems, and law and politics examined the relationship with environmental laws and organizations. Practical arts included a perspective of viewing flora and fauna as resources, and these diverse achievement standards were broadly applied and integrated into the analysis results.

Therefore, this study selected subject-specific achievement standards based on environmental education content elements to cultivate and evaluate the aforementioned elementary school core competencies. Accordingly, achievement standards for subjects that include environmental education content elements, such as science, social studies, technology, and home economics, were primarily selected (see Table 11 and Table 12). Additionally, instrumental subjects like language arts, ethics, art, and music have various functions due to their subject characteristics, so it's possible to reorganize their achievement standards in connection with environmental education.

Evaluation Criteria for Each Core Competency Element and Related Teaching and Learning Methods

In this study, drawing upon the research of Nam Sang-jun (1995) and Choi Seok-jin et al. (2000), various key competency elements and corresponding instructional methods were presented in Table 10. For example, 'autonomy' and 'reflective & insight ability' were deemed appropriate to be cultivated through learning activities structured around instructional methods related to ethics. Also, 'environmental sensitivity' has been confirmed through Nam Sang-jun's

research to be effectively nurtured through practical instructional methods like field surveys or outdoor learning, which are crucial for fostering a sensitive awareness of the environment among students. 'Creativity' can be enhanced through methods like brainstorming or extensive exploration in social studies, while 'problem-solving skills' should center on instructional methods that seek solutions in conflict or problem situations. Additionally, 'the skills to use knowledge and information' can be acquired through methods that enable students to research various materials, and 'awareness of the environmental community and citizenship' is best taught through instructional methods focused on social participation and volunteer activities. Furthermore, methods such as decision-making, panel discussions, and issue debates have been recognized to be broadly applicable in nurturing various elements of key competencies, such as 'critical thinking skills' or 'communication skills'.

Table 11. Analysis results of teaching and learning methods by core competency factors and evaluation criteria(continued)

Core competency	Evaluation Criteria	Teaching and learning methods of environmental education (Nam, 1995)	Teaching and learning methods in each subject (Choi, <i>et al.</i> , 2000)
Autonomy	Independent decision making Assertive self-expression Implementation of self-help behavior	·Values and moral education strategy	·Clarification of values (Ethics Department) ·Value Exploration (Ethics Department) ·Decision-making (Social Studies)
Reflection & insight ability	Self-exploration Self-understanding Searching others Understanding others		
Environment sensibility	Sensitivity Aesthetics and emotional stability Sympathy and compassion	·Outdoor education recreation ·Outdoor survey ·Read historical/present data ·Expression/Exhibition	·Field study learning (Social Studies)
Critical thinking skills	Checking the implicit assumptions Assess the validity of the evidence Consistency of the argument	·Panel discussion and discussion ·Analysis of issues ·Discuss	·Policy Evaluation (Social Studies)
Creativity	Divergent thinking Convergent thinking Creative problem solving Outputs	·Brainstorm	·Social Science Exploration
Problem solving skills	Problem clarification Analysis of cause Development of alternatives Plan and execute Performance evaluation	·Simulation and role play ·Panel discussion and discussion ·Basic case studies ·Analysis of issues	·Resolving value conflicts (Ethics Department) ·STS(Science-Technology- Society)-Problem solving (Social Studies) ·Decision-making (Social Studies)
Skills to use of knowledge and information	Search and access to knowledge and information Understanding and synthesis of knowledge and information Expression and delivery of knowledge and information Evaluation of knowledge and information	·Search for secondary data sources ·Collection of primary data	·Field study learning (Social Studies) ·Fact-finding (Technology and Family Studies)

Table 11. Analysis results of teaching and learning methods by core competency factors and evaluation criteria

Core competency	Evaluation Criteria	Teaching and learning methods of environmental education (Nam, 1995)	Teaching and learning methods in each subject (Choi, <i>et al.</i> , 2000)
Communication skills	Translation	·Panel discussion and discussion	·Discussion on issues (Social Studies)
	Goal setting		
	Self-presentation		
	Message conversion		
Environmental community awareness and citizenship	Sense of unity and mutual influence	·Simulation and role play	·Model activity, role play (Social Studies)
	Common consciousness	·Panel discussion and discussion	·Participation activities in solving environmental problems (Technology, Family Studies)
	Social participation	·Functional training session	·Functions of solving environmental problems (Technology and Family Studies)
	Community service	·Behavior workshop	·Social Participation (Social Studies)
		·Action plan	·Policy Evaluation (Social Studies)
		·Behavioral learning through internship experience and practice in the local community	

An Example of 『Creating a Sustainable Environment』 Program

Based on research result 2), the program development process selected ‘creating a sustainable environment’ as a primary case (Table 12). Under this theme, sub-topics were organized, focusing on the use of resources and the various issues that arise as a result, including the current state, impacts, causes, and participation related to problem resolution. Achievement standards related to the subjects for 5th and 6th graders in elementary school were added to each subtopic, and the program was designed to allow learning through the integration of various subjects.

Additionally, key competency elements that students are expected to cultivate during the learning of each content and achievement standard were placed, and students' learning activities were concretized by referring to the evaluation criteria for each competency. These activities were planned to be related to students' real lives, allowing them to experience directly and perform collaboratively based on the classroom or community. Ultimately, several lesson plans for certain subtopics were created to promote an understanding of the specific composition methods of the program.

Table 12. An example of sustainable environment(main topic) program(continud)

Sub-topic	Achievement standards of related subject	Core competency elements and evaluation criteria	Activities and materials
Change of energy use	·[06Sa02-04] This course explores the changes in information the industrial structure of Korea and the characteristics that appeared in the process of transportation development.	·Ability to utilize knowledge and ·Understanding of knowledge and ·Expression and delivery of knowledge and information	·Find out about each household's car fuel (primary source) ·Investigate changes of resource use according to changes in the industrial structure since the 1960s by group and period (secondary source), and make a presentation
Environmental impact of energy use (weather change)	·[6Sa08-05] Investigate major environmental problems in the global village to find solutions, and cultivate the attitude of global citizens on environmental problems. ·[6Do03-04] ①What are the various global problems we are experiencing, and how can we cultivate moral sensitivity to global problems?	·Ability to reflect ·I'm typing ·Environmental Sensitivity ·Sensitivity ·Sympathy and compassion	·Signs of climate change I feel (changes in summer and winter) ·Learn about changes occurring in various parts of the world due to the effects of climate change

Table 12. An example of sustainable environment(main topic) program

Sub-topic	Achievement standards of related subject	Core competency elements and evaluation criteria	Activities and materials
Identification of causes of environmental problems (climate change)	·[6Gha10-01] Students can explain the properties of gases after generating oxygen and carbon dioxide through experiments and checking their properties.	·Creativity - Diffusion thinking ·Critical thinking skills - Assess the validity of the evidence ·Problem solving skills - Analysis of cause	·Learn about the properties of carbon dioxide ·Think of the classroom as the Earth, generate carbon dioxide and observe changes through simulation and role play ·Identify the causes of climate change
Environmental issues (Climate change) Seeking solutions	·[6Gha08-05] Foster the attitude of global citizens to cooperate in solving major environmental problems of the global village.	·Problem solving skills - Alternative development ·Creativity - Creative problem solving - Outputs ·Communication skills - Goal setting - Self-presentation	·Exploring solutions to reduce carbon dioxide emissions through panel discussions and debates. ·Seeking collective efforts and participation methods to reduce carbon dioxide emissions. ·Exploring the efforts of the government (organizations) in responding to climate change.
Efforts to solve and improve environmental issues (Climate change)	·[6Gha08-05] Foster the attitude of global citizens to cooperate in solving major environmental problems of the global village.	·Environmental Community Awareness and Citizenship - Sense of unity and mutual influence - Common consciousness - Social participation ·Ability to reflect - Self-understanding ·Autonomy - Independent decision making - Implementation of self-help behavior	·Find out about global efforts (groups, institutions, etc.) ·Explore individual efforts to reduce carbon dioxide emissions and what can be done in the classroom ·Finding a collective effort to reduce carbon dioxide and ways to participate and then participating in the activities

Discussion

The discussion of the results of this paper is as follows. First, this study employed the Delphi survey method to collect expert opinions for presenting core competencies for environmental education in elementary schools. The survey results indicated that some core competency elements, such as the use of language, symbols, and text, were deemed less important and thus were excluded or modified. In contrast, more than half of the respondents suggested core competencies related to personal and social responsibility, citizenship, and environmental and social consciousness, which were accordingly integrated. This survey also analyzed the validity of the three areas of core competencies (personality-oriented, thinking-oriented, and relationship-oriented), finding strong consensus and agreement among experts. Additionally, the study ranked the importance of core competencies, identifying environmental sensitivity, environmental and social consciousness and citizenship, communication skills, critical thinking, and self-reflection as top core competencies. It was suggested that different competencies be emphasized for each grade level, with autonomy, reflection, and insight abilities, and environmental sensitivity being important in the early years of elementary school, and critical thinking, problem-solving, and conflict resolution skills being highlighted in the later years (Kim & Han, 2020).

The Delphi survey on core competency items for environmental education reveals dynamic progress in the field, reflecting a deeper understanding of what constitutes effective environmental education and its changing priorities. Modern environmental education transcends traditional cognitive and behavioral aspects, focusing on enhancing a

holistic understanding of the environment and its complexities. This shift responds to the increasing awareness of serious environmental issues, emphasized by both scientists and educators. The consensus highlights the need for education that enables meaningful decision-making and critical thinking about environmental issues, valuing an approach that integrates various perspectives and interdisciplinary evidence. This approach is essential in developing students' environmental literacy and decision-making skills, preparing them to effectively respond to real-world environmental challenges (Ponomarenko et al., 2016).

A new framework for environmental education emphasizes a variety of competencies including personal and social responsibility, critical thinking, creativity, and communication skills. The inclusion of these competencies represents a shift towards a more integrated and comprehensive approach to environmental education, acknowledging the multifaceted nature of environmental issues and the diverse skills needed to address them (Lamanauskas & Makarskaitė-Petkevičienė, 2023). Continuing from previous discussions, the evolving framework of environmental education underscores the importance of integrating various knowledge domains. This integration encompasses humanities, arts, social sciences, and natural sciences, enhancing a holistic understanding of environmental issues (Skowron & Sak-Skowron, 2021). The goal is to develop students' abilities to make informed scientific decisions while considering diverse perspectives when facing complex environmental challenges (Park et al., 2018). This comprehensive approach is essential for cultivating environmental literacy and equipping students with the necessary skills to actively participate in and contribute to sustainable solutions for environmental problems (Kim & Han, 2020). The Delphi survey and subsequent analysis highlight the need for continuous innovation and adaptation in environmental education in response to the growing complexity of environmental issues and sustainability challenges (Seo et al., 2020).

Secondly, this study has provided valuable measurement tools for core competencies that need to be developed in elementary schools. The selection of criteria for assessing core competencies for elementary school environmental education is based on three orientation areas and nine core competencies (Chae & Noh, 2015). These criteria were derived from various studies and then modified or eliminated to fit the specific theme and context. For example, the criteria for 'autonomy' focus on autonomous decision-making, assertive self-expression, and the implementation of self-help behaviors, while 'environmental sensitivity' includes sensitivity, aesthetic sense, emotional stability, and the ability to empathize and sympathize (Lamanauskas & Makarskaitė-Petkevičienė, 2023). Similarly, 'critical thinking ability,' 'creativity,' 'problem-solving ability,' and others have been refined into detailed criteria based on previous research (Mohkamkar, et al., 2021). These criteria can serve not only as tools for assessing students' competency levels but also as guidelines for structuring educational programs, selecting educational content, and setting teaching methods.

The selection of criteria for assessing core competencies in elementary school environmental education plays a crucial role in enhancing the quality of education. These criteria focus on assisting students to effectively think about, solve, and actively participate in environmental issues. According to the 'K–12 Environmental Education: Guidelines for Excellence' provided by the North American Association for Environmental Education (NAAEE, 2021), these guidelines offer a roadmap for achieving environmental literacy for students, parents, educators, and other stakeholders (Ponomarenko et al., 2016). They provide a framework necessary for effectively and comprehensively structuring environmental education programs and curricula from elementary to high school levels. These criteria aid students in developing

sensitivity to the environment, critical thinking, creativity, and problem-solving skills (Skowron & Sak-Skowron, 2021). For instance, criteria for competencies such as 'autonomy', 'reflection and insight', and 'environmental sensitivity' are vital in helping students to independently solve problems, enhance self-understanding, and increase their awareness of others and the environment (Lintangsari et al., 2023). These standards go beyond mere knowledge transfer, supporting students in developing various skills and attitudes necessary to respond to real-world environmental challenges.

Thirdly, this study emphasizes that the development of environmental education programs in elementary schools should focus on cultivating core competencies. In this process, using the Delphi survey to select the themes (content elements and achievement standards) of the environmental education program is crucial (Rahman et al., 2019). It is important to integrate the contents of the 'Children's Green World (2022)' environmental education textbook, designed for 5th and 6th graders, with middle school environmental learning contents, and to concretize the lesson contents for effective evaluation of the foundational measurement tools. Understanding precisely how each core competency element is linked to the achievement standards of each subject, and delivering the content in a manner that students can understand and apply, is essential (Sukma et al., 2020). Such integration assists students in comprehending the continuity between elementary and middle school educational content.

Based on the research by Nam (1995) and Choi (2000), various core competency elements and corresponding teaching methods have been presented. For instance, 'autonomy' and 'reflection and insight abilities' can be effectively developed through learning activities organized via teaching methods related to ethics subjects (Ozyildirim, 2021). Additionally, 'environmental sensitivity' can be effectively cultivated through practical teaching methods such as field research or outdoor learning, which are vital for fostering sensitive awareness of the environment in students (Saito et al., 2019). 'Creativity' can be enhanced through brainstorming or extensive inquiry in social sciences, while 'problem-solving ability' should be centered around teaching methods that focus on finding solutions in problematic or conflict situations (Lintangsari et al., 2023). These educational programs aid students in understanding environmental issues across various academic fields and participating in problem-solving. This represents an integrated approach to environmental education, aiming to nurture students as conscious citizens regarding the environment (Rahman et al., 2019). UNESCO (2021) urges the incorporation of Education for Sustainable Development (ESD) as a core component of all educational systems by 2025. This plays a significant role in ensuring that students are equipped with skills in social and emotional learning, collaboration, problem-solving, and resilience development (Chae & Noh, 2015). The development of environmental education programs in elementary schools is crucial in enabling students to gain a deep understanding of the environment and develop necessary competencies. Such programs allow students to directly experience and participate in activities closely connected to real life. According to UNESCO, Education for Sustainable Development (ESD) should become a vital part of all education systems, facilitating students in developing various skills and learning effective responses to global environmental challenges (Lintangsari et al., 2023).

Conclusion and Suggestion

In this study, we discussed the development of core competencies suitable for the direction of education that enhances capabilities newly demanded by the rapid changes in future society, and the necessity of elementary school environmental education, which is increasingly emphasized. We also discussed plans for outlining an elementary environmental education program for nurturing these competencies. The research findings can be summarized as follows:

First, we clarified the essential core competency elements that need to be emphasized in elementary environmental education. Based on research on the core competencies required in existing secondary environmental subjects, we conducted a Delphi survey among experts who have studied or are currently studying environmental education, considering the core competency requirements that elementary students should develop and the competencies suggested in secondary environmental subjects. By analyzing the opinions of expert panels, we identified nine core competency elements and their meanings within three major areas: personality-oriented, thinking-oriented, and relationship-oriented. These competencies include 'autonomy', 'reflective & insight ability', 'environmental sensitivity', 'problem-solving skills', 'critical thinking skills', 'creativity', 'skills to use knowledge and information', 'communication skills', and 'environmental community awareness and citizenship'.

The research results from the Delphi survey indicate that most of these competencies overlap significantly with those emphasized in other subjects. Unique competencies required in the specific area of environmental education were 'environmental sensitivity' and 'environmental community awareness and citizenship'. Therefore, there is a need to systematically structure and discuss such competencies.

Secondly, based on the selected core competency elements of elementary environmental education, we developed tools to measure them. We searched for prior studies discussing measurement tools for individual core competency elements, and selected those tools that were deemed to have similar meanings and emphases to the core competency elements defined in this study. These tools were then modified to suit the subjects and characteristics of our research. As a result, we organized 34 evaluation criteria within the nine core competency elements and developed related measurement questions. The measurement tools for core competency elements are not only capable of assessing the degree of competency cultivation but can also be used to choose teaching-learning methods, among other things, by referring to the attributes and details of the measurement tools as standards for structuring programs.

Third, a proposal was made for the blueprint of an elementary environmental education program for fostering key competencies. In prior studies on the evolution of environmental and educational curricula in Korea, it has been highlighted that environmental education must move towards a convergent style of education that integrates various elements, in light of the growing importance of education for sustainable development. Therefore, methods for fostering key competencies were discussed by reorganizing the content currently presented fragmentarily in elementary subjects around the theme of environment. The program's blueprint approach applied a theme-integrated approach, analyzing related literature to establish a program blueprint phase that can preserve the characteristics of fostering key competencies, which is a feature of this study.

Through this study, we identified the core competencies to be nurtured in environmental education at the elementary

school and derived tools for measuring these competencies. We placed a step for fostering core competencies in the middle of the lesson composition stages of integrated thematic approaches, allowing for consideration of materials and teaching-learning methods for nurturing these competencies during lesson planning. Furthermore, when outlining the actual environmental education program, we analyzed the environmental education content elements and the achievement standards for each subject in the 5th and 6th grades of elementary school. Based on this, we established major and minor topics and set principles for composing detailed activities with the goal of nurturing the identified core competencies. By presenting a method to structure environmental education programs using actual achievement standards in the curriculum, we enabled more effective learning of objectives that need to be achieved in other subjects through environmental topics. This allows for the simultaneous attainment of learning objectives needed in other subjects while learning about environmental topics, providing a method for efficient and continuous learning of environmental education within the curriculum. The results of this study enable the selection of various environmental topics depending on the circumstances of the region or school and the characteristics of the teacher, and the composition of lessons in a flexible manner using various methods, based on the core competency elements the teacher wishes to foster, referring to the measurement tools and leveraging their expertise.

Future research should focus on applying educational programs directly in classrooms to develop core competencies for environmental education among 5th and 6th graders in elementary schools. It is crucial to adjust the number of measurement items and enhance the reliability and validity by surveying the questionnaire of the measurement tools. Consequently, by improving the introduced environmental education programs, it will be possible to harmoniously develop core competencies for environmental education among elementary school students.

Conflicts of Interest

The author(s) declared no conflicts of interest.

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