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RESEARCH ARTICLE

Characteristics of "Values and Attitudes" Embedded in Achievement Standards of the 2022 Revised Common Science Curriculum

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ABSTRACT

This study aims to longitudinally analyze the distribution characteristics and developmental pathways of "Values and Attitudes" embedded in the achievement standards of the 2022 Revised Common Science Curriculum (Grades 3-9). An analytical framework with nine sub-elements was developed based on curriculum documents to analyze all 189 achievement standards. The results confirmed that the 2022 Revised Curriculum establishes a two-track strategy considering students' cognitive development and the nature of the subject. First, in the four core domains (Matter, Motion and Energy, Life, Earth and Space), a distinct qualitative shift was observed as school levels increased from a focus on "Sensitivity" (lower elementary) to "Aesthetic Value" (middle school). This signifies a deepening educational goal toward fostering a scientific worldview, moving from affective interest to an understanding of the logical beauty of laws and principles. Second, the "Science and Society" domain demonstrated a unique developmental pathway for citizenship, expanding from "Contribution to a Sustainable Society (Practice)" in elementary school to "Enjoyment of Science Culture (Communication)" and "Usefulness (Career)" in middle school. This study empirically validates the systematic affective design of the common curriculum and suggests the necessity of dualized teaching and learning designs reflecting the characteristics of school levels and domains.

Keywords: 2022 revised science curriculum, analysis of achievement standards, common curriculum, developmental pathway, values and attitudes.

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Introduction

Background and Necessity of the Research

The uncertain modern society, characterized by the rapid advancement of artificial intelligence, the deepening climate crisis, and infectious disease pandemics, demands fundamental changes

in the competencies required of future citizens. Emerging within this context, the 2022 Revised National Curriculum presents "proactive individuals with inclusiveness and creativity" as its human image and has innovated educational content and methods by reflecting the "transformative competencies" and "student agency" emphasized by the OECD Education 2030 project (MOE, 2021; MOE, 2022a; OECD, 2005, 2016, 2019).

This transformation is most evident in the restructuring of the subject-matter content system. In a departure from the traditional content framework, the 2022 Revised National Curriculum organized content into three categories—"Knowledge and Understanding", "Process and Skills", and "Values and Attitudes"—and developed achievement standards based on this structure (Yoon & On, 2022). Numerous studies indicate that this three-dimensional categorization of educational content and achievement standards originates from Bloom's Taxonomy (Krathwohl, 2002; Miller, 2004). Bloom's Taxonomy has long been utilized across major countries for the alignment of curricula (educational goals and achievement standards) with teaching, learning, and assessment (Dong et al., 2015; Hachoumi et al., 2025). This provides the background for the recent introduction of the "Values and Attitudes" domain in the science curriculum and aligns with discussions to expand the goals of science education beyond the acquisition of knowledge and the mastery of inquiry skills. Ultimately, this shift aims to foster "Scientific Citizenship", enabling students to make rational decisions based on scientific literacy and to participate practically in solving community problems (Park, 2024).

Achievement standards are specific statements of the totality of the knowledge, skills, and attitudes that students must reach through learning. Therefore, for the curriculum to be substantially established in schools, it is essential to closely examine how these intentions are implemented in the "achievement standards", which serve as the key mechanism of the national curriculum and the direct criteria for textbook development and teaching and learning (Jho et al., 2023; Kim & Park, 2022; Lee, 2024). However, previous studies on the science curriculum have primarily focused on exploring directions at the general guideline level or analyzing achievement standards limited to specific school levels or themes (Kim et al., 2024; Lee, 2025; Lee & Hong, 2025; Lee & Lee, 2025). In particular, longitudinal research analyzing how the newly established affective domain of "Values and Attitudes" is designed across the entire seven-year common curriculum is lacking from the 3rd grade of elementary school to the 3rd grade of middle school.

Students' affective characteristics change with their cognitive development stages. According to Piaget's theory, elementary students in the concrete operational stage and middle school students in the formal operational stage differ in how they perceive the world and assign values (Inhelder & Piaget, 2013). Therefore, "Values and Attitudes" in the curriculum must also have a hierarchical path that deepens and develops from "interest and sensitivity" to "logical value recognition" and "social practice" as the school level increases. If achievement standards do not reflect this developmental pathway or are presented in a disjointed or uniform manner, the affective goals of the curriculum are unlikely to be effective in the classroom.

Accordingly, this study aims to comprehensively analyze the distribution and characteristics of "Values and Attitudes" embedded in all achievement standards of the 2022 Revised Common Science Curriculum (Grades 3-9). This study empirically verifies how the abstract goals contained in the curriculum documents are materialized and differentiated according to grade clusters and subject domains at the achievement standard level. The results of this study will provide

concrete and practical implications for textbook development considering the connection between school levels and for instructional design considering students' affective development.

Research Purpose and Questions

The purpose of this study is to analyze the domain-specific distribution and developmental changes according to school levels of "Values and Attitudes" embedded in the achievement standards of the 2022 Revised Common Science Curriculum (Grades 3-9). The specific research questions are as follows:

First, what differential characteristics does the distribution of "Values and Attitudes" show across the five subject domains (Motion and Energy, Matter, Life, Earth and Space, Science and Society)?

Second, what developmental differences does the distribution of "Values and Attitudes" show according to changes in school levels (Elementary Grades 3-4, Grades 5-6, Middle School)?

Theoretical Background

Background and Meaning of Introducing 'Values and Attitudes' in the 2022 Revised Science Curriculum

The 2022 Revised National Curriculum presents "proactive individuals with inclusiveness and creativity" as the vision for the human image to respond to the uncertainties of the future society. To realize this vision, the curriculum restructured the subject content system into "Knowledge and Understanding", "Process and Skills", and "Values and Attitudes" (MOE, 2022a). In particular, the explicit introduction of the "Values and Attitudes" domain in the science curriculum holds significant meaning in that it aims to cultivate qualities as democratic citizens with scientific literacy, moving beyond the traditional inquiry-centered education (Kim et al., 2024; Shin, 2022).

Furthermore, while "Scientific Attitudes" in the 2015 Revised Curriculum (MOE, 2015) were primarily confined to internal norms necessary for scientific inquiry, such as interest, curiosity, objectivity, and cooperation, the "Values and Attitudes" of the 2022 Revised Curriculum have expanded their scope to the realms of value internalization and social practice, encompassing the aesthetic value of science, social responsibility, and ecological sensitivity (MOE, 2022b). This suggests that science education should go beyond the stages of acquiring scientific knowledge and fostering inquiry skills, focusing on helping students form positive values regarding nature and life and grow into practical agents who make rational decisions concerning complex Socio-Scientific Issues (SSI). Such shifts align with the "Transformative Competencies" emphasized in the OECD Education 2030 project (OECD, 2019) and reflect the curriculum's intention to lay the foundation for scientific citizenship from the elementary level.

These curricular changes are closely linked to the influence of the Next Generation Science Standards (NGSS) in the United States and the Korean Science Education Standards (KSES). Just as the NGSS (NGSS Lead States, 2013) emphasized three-dimensional learning consisting of Core Ideas, Practices, and Crosscutting Concepts, the KSES (Song et al., 2019) presented performance expectations for each domain in terms of competencies, knowledge, and

participation and practice, centered on Big Ideas. Comparing these with the subcategories of the content system in the 2022 Revised Curriculum, knowledge is interpreted as "Knowledge and Understanding", competency as "Process and Skills", and participation and practice as "Values and Attitudes". Thus, the 2022 Revised Science Curriculum seeks a balance between cognitive learning and affective development by elevating the affective domain to an independent category called "Values and Attitudes" (Kwon & Lee, 2024).

The expansion of "Attitude" to "Values and Attitudes" in the 2022 Revised Curriculum is not a change limited to science but is based on a general direction to expand learning objectives from cognitive achievement to social practice and civic competency across all subjects (MOE, 2022a). According to the guidelines for stating the content system in the revised curriculum, "Values and Attitudes" refer to unique values and attitudes that can be cultivated through learning activities in the relevant subject across all grade levels. Generally, "values" are belief systems that individuals perceive as important, serving as criteria for judgment and behavior (Rokeach, 1973), and in an educational context, they are deeply involved in how learners interpret and participate in society and the world. While "Values and Attitudes" in the science curriculum embrace this general concept of values, they are specified as subject-specific goals of cultivating "Scientific Citizenship"—making rational judgments on social issues based on scientific knowledge and evidence and participating in solving community problems (Kim & Park. 2022; Lee & Hong, 2025). This represents a shift requiring students to recognize science not as a means for personal achievement but as a tool for social responsibility and practice, moving beyond simple knowledge acquisition or inquiry skill mastery.

From this perspective, "Values and Attitudes" in the 2022 Revised Science Curriculum encompass the recognition of the aesthetic value of science, social responsibility, and the will to practice for sustainability. It reflects the curriculum's philosophy to systematically foster competencies as citizens who participate in decision-making based on scientific literacy in uncertain future situations.

Hierarchy and Connectivity of 'Values and Attitudes' in the Common Curriculum

The 2022 Revised Science Curriculum designates the period from the third grade of elementary school to the third grade of middle school as a single "Common Curriculum" and emphasizes organic connectivity between grade levels (MOE, 2022a). In the case of science, emphasis was placed on reflecting "Process and Skills" and "Values and Attitudes" among the three sub-elements of the content system, incorporating international assessment frameworks—including the OECD PISA 2025 framework—as well as domestic and international curriculum trends. Because "Knowledge and Understanding", which has long been emphasized in science, is established as what students should ultimately understand and know, "Process and Skills" are viewed as scientific thinking and inquiry processes and procedures, while "Values and Attitudes" are regarded as the values and attitudes expected through science subject activities, making them key issues of the revision (Shin, 2022).

In science education, "Values and Attitudes" refer to an individual's internal belief system and behavioral tendencies related to science and science learning. This consists largely of the perception of the discipline of science itself (values), the mindset exhibited during the process of conducting scientific inquiry (attitudes), and social behavior based on these (participation and practice). The nine detailed elements utilized in this study can be specified as follows based on curriculum documents (MOE, 2022b).

Scientific Values involve internalizing the nature and importance of science, including "aesthetic value," which involves sensing beauty in the order and laws of nature, "social value" in recognizing that science contributes to human welfare and social development, "scientific usefulness" in perceiving its help in solving real-life problems, and "sensitivity" as wonder and curiosity about natural phenomena. Scientific Attitudes are the tendency to think and act like a scientist. These consist of "open-mindedness" in making rational judgments based on evidence and being open to new evidence, "ethics" meaning honesty in the inquiry process and respect for life, and "scientific creativity" in proposing new ideas beyond existing frameworks. Participation and Practice refer to moving toward actual action based on internalized values and attitudes. This includes the will to "contribute to a safe and sustainable society," such as environmental problem-solving or energy conservation, and "enjoying scientific culture" by appreciating science as a culture and participating in communication. The newly established "Values and Attitudes" domain should not simply repeat the same elements but should possess a hierarchical structure that deepens and expands according to the learner's growth and cognitive development.

According to the taxonomy of educational objectives in the affective domain (Krathwohl et al., 1964), the valuing process progresses from simple 'Receiving' and 'Responding' to 'Valuing,' 'Organization,' and 'Characterization.' This implies that in the early stages of the common curriculum, an approach centered on interest in scientific phenomena and sensitivity is required, while in the middle school stage, logical understanding of the intrinsic value of science and the establishment of a systematic value system are required. From this perspective, the introduction of 'Values and Attitudes' in the 2022 Revised Curriculum can be interpreted as an attempt to build a systematic developmental pathway of affective competencies as a core element of scientific literacy, beyond simple attitude cultivation (Yang, 2019).

Cognitive Development Stages and Qualitative Transition of the Affective Domain

This study adopts Piaget's theory of cognitive development as a theoretical framework for analyzing the developmental pathway of 'Values and Attitudes.' Since elementary students are generally in the 'Concrete Operational Stage,' they think through concrete and observable objects or experiences (Inhelder & Piaget, 2013). Therefore, 'Values and Attitudes' embedded in the achievement standards of the common curriculum science need to be linked closely with students' experiences, such as direct 'sensitivity' to natural phenomena or 'usefulness' of tools in daily life, rather than abstract values (Choi & Paik, 2015).

On the other hand, the middle school period corresponds to the transition to the 'Formal Operational Stage,' where hypothetico-deductive thinking about abstract concepts, laws, and principles becomes possible. Students in this period can discover logical consistency and order in abstract systems such as the invisible law of conservation of energy or the periodic table of elements. Therefore, 'Values and Attitudes' in middle school science must undergo a qualitative transition beyond sensory interest to understanding the aesthetic value of scientific theories and logical judgment and practice on social issues (Kim & Park, 2022).

Based on these theoretical premises, this study aims to empirically analyze how the achievement standards of the common curriculum actually implement this developmental transition.

Methods

Subject of Analysis

This study targets the entire common curriculum of the 2022 Revised Science Curriculum. The data for analysis consist of a total of 189 achievement standards from the grade clusters of elementary 3–4 (51 standards), elementary 5–6 (51 standards), and middle school 1–3 (87 standards), as specified in Ministry of Education Notice No. 2022-33 (MOE, 2022b). To ensure the objectivity of the analysis, the scope was not limited to the sentences of the achievement standards themselves; rather, "Inquiry Activities", "Explanations of Achievement Standards", and "Considerations for the Application of Achievement Standards"—which specify the intent and scope of the respective standards—were all included as units of analysis for a comprehensive examination.

This study does not presuppose that all achievement standards in the 2022 Revised Science Common Curriculum incorporate "Values and Attitudes" to an equal degree. Instead, the purpose of defining the scope of this analysis is to empirically examine the presence and specific patterns of "Values and Attitudes" elements across the entire set of achievement standards presented in the common curriculum. Although the 2022 Revised Curriculum organized the content system into the three categories of "Knowledge and Understanding", "Process and Skills", and "Values and Attitudes", this does not necessarily imply that every individual achievement standard must reflect all three categories equally. In practice, some achievement standards are phrased with a primary focus on cognitive understanding or the acquisition of inquiry skills, while affective elements may remain implicit or secondary.

Accordingly, this study comprehensively interpreted the educational intentions manifested in the achievement standards and their accompanying explanations, including them in the analysis only when "Values and Attitudes" were explicitly or latently present. Rather than assuming the universal existence of "Values and Attitudes", this approach serves as an analytical strategy to empirically demonstrate how affective goals are actually distributed across the common curriculum.

Analysis Criteria and Procedure

Analysis Framework

The analytical framework for "Values and Attitudes" in this study was developed inductively through a systematic analysis of relevant prior research, based on the components of "Values and Attitudes" fundamentally presented in the 2022 Revised Science Curriculum document (MOE, 2022b). To achieve this, descriptions related to "Values and Attitudes" in the general curriculum guidelines and the science-specific curriculum were repeatedly reviewed. Theoretical discussions concerning scientific values, scientific attitudes, and scientific citizenship were comprehensively examined to establish the primary structure of the analytical framework for "Values and Attitudes".

Subsequently, to ensure the conceptual validity of the framework, a face validity review was conducted on the draft version by an expert group of five, consisting of one professor of education, two professors of science education, and one elementary and one secondary science teacher with extensive experience in science curricula and instruction. The expert review focused on whether each upper category and sub-element appropriately reflected the curriculum's definitions

of "Values and Attitudes" and whether the distinctions between sub-elements were conceptually clear. Based on this feedback, the names and descriptive phrases of certain sub-elements were revised and supplemented.

Through this process, the analytical framework for "Values and Attitudes" in achievement standards was organized into three upper categories—"Scientific Values", "Scientific Attitudes", and "Participation and Practice"—and nine elements based on semantic similarity and functional differentiation within each category, as shown in Table 1.

Table 1. Analytical framework for 'values and attitudes' in the 2022 revised science curriculum

Category	Element	Characteristics
1. Scientific Values	1-1. Aesthetic Value of Science	Value of appreciating intellectual beauty in the order, patterns, regularity, logical simplicity, and harmony inherent in natural phenomena or scientific theories.
	1-2. Social Value of Science	Value of recognizing that science contributes to the development of human civilization and society as a whole, such as disease treatment and technological innovation, and plays an important role in solving social issues.
	1-3. Usefulness of Science	Value of recognizing that scientific knowledge and methods provide practical and concrete help in various aspects of individual daily life or professional life.
	1-4. Sensitivity to Nature & Science	Affective value of feeling the wonder of natural phenomena or respect for life, and feeling joy, interest, and curiosity in inquiry activities themselves.
2. Scientific Attitudes	2-1. Scientific Creativity	Attitude of proposing various and new ideas or inquiry methods, deviating from existing ways, and trying to solve problems creatively.
	2-2. Ethics of Scientific Activity	Attitude related to norms to be observed throughout the scientific inquiry process, such as honest recording and presentation of evidence, respect for others' research, respect for life, and compliance with laboratory safety rules.
	2-3. Openness to Problem Solving	Flexible attitude of acknowledging that one's thoughts may be different, respecting objective evidence and reviewing it critically, and modifying one's thoughts if there are reasonable grounds.
3. Participation & Practice	3-1. Contribution to Sustainable Society	Practical will to actively participate in and contribute to solving community problems such as safety, environment, and energy in daily life and society based on knowledge and values obtained through science learning.
	3-2. Enjoyment of Science Culture	Practical attitude of accepting and enjoying science as part of culture in daily life, such as enjoying science-related events, books, and media, and participating in scientific communication (writing, presentation, sharing).

Analysis Method

In deriving the core elements of "Values and Attitudes" embedded in the achievement standards, we focused on the explicit learning actions manifested in the achievement standard statements. Furthermore, when supplementary materials such as "Inquiry Activities", "Explanations of Achievement Standards", and "Considerations for Application of Achievement Standards" were provided, the educational focus emphasized in these materials was comprehensively considered. Accordingly, in cases where a single achievement standard clearly aimed at two or more affective goals, the relevant sub-elements were double-coded.

To pursue the accuracy of the analysis, coding was performed while providing the rationale for the classification of each "Values and Attitudes" element. The requirement to provide these rationales was intended not only to ensure that analysts conducted logically valid assessments but also to serve as a basis for verifying the validity of the classifications during cross-comparisons and discussions among analysts.

For example, an analysis of "Values and Attitudes" embedded in achievement standard [4Sci01-04] of the "Motion and Energy" domain is as follows:

• [Achievement Standard 4Sci01-04]: Understand that using tools such as levers and inclined planes changes the

amount of force required to lift objects, and investigate and share how these tools are used in daily life.

• [Considerations for Application]: Social Network Services (SNS) can be used when sharing investigated content, and presentation materials can be created using text and drawings.

• Analysis 1: Since it leads to the direct recognition that the scientific principles of tools like levers and inclined planes are highly useful in solving real-life difficulties (e.g., lifting heavy objects), it was considered to contain the "Scientific Usefulness" element of the "Scientific Values" category.

• Analysis 2: The action of "investigating and sharing" in the achievement standard and "using SNS" in the considerations for application can be classified as the "Enjoying Scientific Culture" element of the "Participation and Practice" domain, which involves producing and sharing knowledge.

• Analysis 3: To share the investigated content as suggested in the achievement standard, the considerations for application propose "creating presentation materials using text and drawings". This requires reconstructing information and expressing effective presentation materials with one's own ideas; thus, it can be classified as the "Scientific Creativity" element of the "Scientific Attitudes" domain.

Representative examples classified through this analytical process for each science domain are as follows (Table 2, 3, 4, 5, 6).

Table 2. Examples of analysis and classification of "values and attitudes" for the achievement standards in the "science and society" domain

Domain	Achievement Standard	Rationale for Classification	Category	Element
Science and Society	[6Sci16-01] Investigate problems that may occur in future society and discuss ways science can contribute to solving them.	• By discussing ways science can contribute to solving future problems, students are led to recognize the noble social value of science. Thus, it is classified as "Scientific Social Value" under the "Scientific Values" category.	1. Scientific Values	1-2. Scientific Social Value
		• In the "Considerations for Application", teaching that science and technology are not the solutions to all problems allows for critical reflection on the role and limitations of science. This fosters a balanced perspective and open-mindedness toward various viewpoints for solving complex social problems; hence, it is classified as "Open-mindedness for Solving Scientific Problems" under the "Scientific Attitudes" category.	2. Scientific Attitudes	2-3. Open-mindedness for Solving Scientific Problems
		• The "Explanations of Achievement Standards" aims to cultivate qualities as future citizens who contribute to creating a safe and sustainable society by participating in solving world problems. Thus, it is classified as "Contribution to a Safe and Sustainable Society" under the "Participation and Practice" category.	3. Participation and Practice	3-1. Contribution to a Safe and Sustainable Society

Table 3. Examples of analysis and classification of "values and attitudes" for the achievement standards in the "motion and energy" domain

Domain	Achievement Standard	Rationale for Classification	Category	Element
Motion and Energy	[9Sci05-04] Explain force and force eq uilibrium in various cases and design devices or in struments using the charac teristics of force in daily life.	• Linking force and force equilibrium to "instruments or devices used in daily life" shows that scientific principles provide "practical help" in making individual lives more convenient. Thus, it is classified as "Scientific Usefulness" under the "Scientific Values" category.	1. Scientific Values	1-3. Scientific Usefulness
		• Going beyond simply knowing the principle to "designing" a device by applying it is an activity of "devising new solutions". Thus, it is classified as "Scientific Creativity" under the "Scientific Attitudes" category.	2. Scientific Attitudes	2-1. Scientific Creativity

Table 4. Examples of analysis and classification of "values and attitudes" for the achievement standards in the "matter" domain

Domain	Achievement Standard	Rationale for Classification	Category	Element
Matter	[6Sci05-01] Separate solid mixtures with different particle sizes and liquid mixtures that do not mix evenly.	• The "Considerations for Application" emphasizes that "most substances exist as mixtures, so separating them is necessary to obtain required substances". This highlights that mixture separation is a practical and useful process rather than a mere laboratory activity. Thus, it is classified as "Scientific Usefulness" under the "Scientific Values" category.	1. Scientific Values	1-3. Scientific Usefulness
		• Performing experiments safely by choosing appropriate methods based on material properties during separation involves cultivating honesty, responsibility, and safety awareness required in scientific activities. Thus, it is classified as "Ethics of Scientific Activities" under the "Scientific Attitudes" category.	2. Scientific Attitudes	2-2. Ethics of Scientific Activities

Table 5. Examples of analysis and classification of "values and attitudes" for the achievement standards in the "life" domain

Domain	Achievement Standard	Rationale for Classification	Category	Element
Life	[9Sci21-04] U nderstand the sig nificance and p rinciples of Mendel's genetic ex periments and in vestigate and co mmunicate collab oratively about genetic phenomena where Mendel's laws apply.	• Understanding the "regularity" and "patterns" of genetic phenomena through Mendel's laws (law of segregation, law of independent assortment) is an activity of discovering the "logical order" inherent in nature. Thus, it is classified as "Aesthetic Value of Science" under the "Scientific Values" category.	1. Scientific Values	1-1. Aesthetic Value of Science
		• By explicitly requiring collaborative communication after investigating genetic phenomena, this standard aims to foster participatory attitudes in sharing scientific knowledge and enjoying scientific culture. Thus, it is classified as "Enjoying Scientific Culture" under the "Participation and Practice" category.	3. Participation and Practice	3-2. Enjoying Scientific Culture

Table 6. Examples of analysis and classification of "values and attitudes" for the achievement standards in the "earth and space" domain

Domain	Achievement Standard	Rationale for Classification	Category	Element
Earth and Space	[4Sci06-03] Understand the difference between high and low tides and persuade or promote the value and necessity of conserving tidal flats.	• Investigating the value and necessity of conserving tidal flats allows scientific understanding of ecological importance to hold significant social value, such as in environmental policy decisions. Thus, it is classified as "Scientific Social Value" under the "Scientific Values" category.	1. Scientific Values	1-2. Scientific Social Value
		• The "Considerations for Application" explicitly mentions knowing the "biodiversity of tidal flats" and the "value of environment and life" to "cultivate ecological sensitivity". Thus, it is classified as "Sensitivity toward Nature and Science" under the "Scientific Values" category.	1. Scientific Values	1-4. Sensitivity toward Nature and Science
		• Activities to persuade or promote conservation encourage participation in practical actions for environment preservation and a sustainable society based on scientific knowledge. Thus, it is classified as "Contribution to a Safe and Sustainable Society" under the "Participation and Practice" category.	3. Partici pation and Practice	3-1. Contribution to a Safe and Sustainable Society

Data Processing and Reliability Assurance

To ensure the reliability of the analysis, three science education experts independently coded the data, followed by cross-validation. The average Cohen's Kappa value, calculated pair-wise among the three experts, was .87, indicating a high level of reliability. Any inconsistent items were resolved through discussion and consultation until all analysts reached a consensus. Based on the analysis results, the distribution of categories and elements for the achievement

standards was organized by school level and subject domain. To adjust for differences in the number of achievement standards per level and domain, the "inclusion ratio relative to the number of achievement standards (%)" was calculated, thereby ensuring the validity of the longitudinal comparative analysis.

Results and Discussion

This study analyzed the distribution of 'Values and Attitudes' elements targeting 189 achievement standards of the '2022 Revised Common Science Curriculum'. The analysis results were discussed by dividing them into the overall developmental pathway (by grade cluster) and characteristics by five subject domains.

Longitudinal Distributional Characteristics of 'Values and Attitudes' in Achievement Standards

The analysis of the distribution of 'Values and Attitudes' elements as the school level increased from elementary 3rd grade to middle school 3rd grade is shown in Table 7.

Table 7. Longitudinal distribution of 'values and attitudes' types in common curriculum

Category	Element	Elem. 3-4 (N=51)	Elem. 5-6 (N=51)	Middle school (N=87)	Total (N=189)
1. Scientific Values	1-1. Aesthetic Value	6 (11.8)	13 (25.5)	65 (74.7)	84 (44.4)
	1-2. Social Value	6 (11.8)	4 (7.8)	9 (10.3)	19 (10.1)
	1-3. Usefulness	8 (15.7)	10 (19.6)	18 (20.7)	36 (19.0)
	1-4. Sensitivity	10 (19.6)	8 (15.7)	10 (11.5)	28 (14.8)
2. Scientific Attitudes	2-1. Creativity	6 (11.8)	6 (11.8)	5 (5.7)	17 (9.0)
	2-2. Ethics	4 (7.8)	5 (9.8)	6 (6.9)	15 (7.9)
	2-3. Openness	6 (11.8)	4 (7.8)	3 (3.4)	13 (6.9)
3. Participation & Practice	3-1. Sustainable Society	8 (15.7)	8 (15.7)	6 (6.9)	22 (11.6)
	3-2. Science Culture	8 (15.7)	10 (19.6)	30 (34.5)	48 (25.4)
Total		62	68	152	282

Note: The numbers in parentheses ( ) represent the percentage (%) of the element included relative to the number of achievement standards (N) for the corresponding grade cluster.

The results of the analysis revealed a distinct trend in which the emphasis of affective goals undergoes a qualitative shift from "emotional interest" to "logical understanding" as grade levels increase. This affective transition aligns with international research findings indicating that interest and emotional responses in science learning serve as initial motivations, which subsequently deepen into a recognition of the value regarding the structural beauty and explanatory power of scientific theories as learners' cognitive development progresses (Krapp & Prenzel, 2011; Osborne et al., 2003; Schreiner & Sjøberg, 2010).

The most striking change was observed in the elements '(1-1) Aesthetic Value of Science' and '(1-4) Sensitivity to Nature and Science'. In Elementary Grades 3-4, the introductory period of science learning, 'Sensitivity' appeared highest at 19.6%. However, entering Grades 5-6, 'Aesthetic Value' increased to 25.5%, overtaking sensitivity, and in the middle school stage, it exploded to 74.7%, becoming the overwhelming core affective goal of the achievement standards.

On the other hand, 'Sensitivity' showed a decreasing trend to 11.5% in middle school.

This result reflects a sophisticated curriculum design that aligns with Piaget's stages of cognitive development (Inhelder & Piaget, 2013). In the concrete operational stage (lower elementary), it is important to form a positive attitude toward science through 'Sensitivity' by directly observing and experiencing natural phenomena. Conversely, for middle school students entering the formal operational stage, it is effective to make them feel 'Aesthetic Value' by grasping the universal laws and principles of nature through abstract thinking. In other words, the 2022 Revised Curriculum induces the establishment of a scientific worldview through a qualitative shift from 'science felt with the heart' to 'science understood and admired with the head'.

Furthermore, it is noteworthy that the proportion of "3-2. Enjoying Scientific Culture" significantly increased from the 15–19% level at the elementary stage to 34.5% at the middle school stage. These results align with the recent international trend in science education that encourages experiencing science as a cultural and social practice rather than a mere accumulation of individual knowledge (Falk & Dierking, 2013; Irwin, 2014). In particular, the perspective that civic identity is formed through scientific communication and participation supports the findings of this study, in which "Enjoying Scientific Culture" is strengthened at the secondary level (Dawson, 2019).

Longitudinal Distribution by Domain and Comparison Between School Levels

The results of analyzing the distribution ratio of 'Values and Attitudes' elements according to school levels for each of the five subject domains of the Common Science Curriculum are shown in Table 8.

Table 8. Longitudinal distribution of 'values and attitudes' by domain in common curriculum

Domain	School Level (N)	1-1. Aesthetic	1-2. Social	1-3. Useful	1-4. Sensitive	2-1. Creative	2-2. Ethics	2-3. Open	3-1. Sustainable	3-2. Culture
Motion & Energy	El. 3-4 (10)	1 (10.0)	1 (10.0)	6 (60.0)	3 (30.0)	2 (20.0)	1 (10.0)	0 (0.0)	1 (10.0)	2 (20.0)
	El. 5-6 (14)	5 (35.7)	0 (0.0)	7 (50.0)	2 (14.3)	4 (28.6)	1 (7.1)	0 (0.0)	3 (21.4)	3 (21.4)
	Middle (16)	14 (87.5)	0 (0.0)	8 (50.0)	2 (12.5)	1 (6.3)	0(0.0)	0 (0.0)	1 (6.3)	5 (31.3)
Matter	El. 3-4 (10)	3 (30.0)	0 (0.0)	3 (30.0)	3 (30.0)	3 (30.0)	1 (10.0)	2 (20.0)	1 (10.0)	1 (10.0)
	El 5-6 (14)	4 (28.6)	3 (21.4)	4 (28.6)	1 (7.1)	0 (0.0)	2 (14.3)	3 (21.4)	4 (28.6)	3 (21.4)
	Middle (23)	19 (82.6)	0 (0.0)	4 (17.4)	0 (0.0)	1 (4.3)	4 (17.4)	1 (4.3)	0 (0.0)	6 (26.1)
Life	El. 3-4 (15)	7 (46.7)	4 (26.7)	5 (33.3)	8 (53.3)	5 (33.3)	1 (6.7)	6 (40.0)	1 (6.7)	4 (26.7)
	El 5-6 (6)	2 (33.3)	0 (0.0)	1 (16.7)	3 (50.0)	1 (16.7)	0 (0.0)	0 (0.0)	1 (16.7)	2 (33.3)
	Middle (21)	18 (85.7)	1 (4.8)	0 (0.0)	3 (14.3)	2 (9.5)	0 (0.0)	0 (0.0)	1 (4.8)	7 (33.3)
Earth& Space	El. 3-4 (10)	3 (30.0)	1 (10.0)	1 (10.0)	7 (70.0)	0 (0.0)	3 (30.0)	0 (0.0)	2 (20.0)	3 (30.0)
	El. 5-6 (12)	9 (75.0)	0 (0.0)	1 (8.3)	3 (25.0)	1 (8.3)	1 (8.3)	0 (0.0)	0 (0.0)	4 (33.3)
	Middle (20)	14 (70.0)	5 (25.0)	2 (10.0)	5 (25.0)	0 (0.0)	2 (10.0)	0 (0.0)	2 (10.0)	7 (35.0)
Science& Society	El. 3-4 (6)	0 (0.0)	3 (50.0)	2 (33.3)	1 (16.7)	1 (16.7)	0 (0.0)	2 (33.3)	4 (66.7)	1 (16.7)
	El. 5-6 (5)	0 (0.0)	3 (60.0)	2 (40.0)	1 (20.0)	0 (0.0)	0 (0.0)	1 (20.0)	4 (80.0)	2 (40.0)
	Middle (7)	0 (0.0)	3 (42.9)	4 (57.1)	0 (0.0)	1 (14.3)	0 (0.0)	2 (28.6)	2 (28.6)	5 (71.4)

Note: The numbers in parentheses ( ) represent the percentage (%) of the element included relative to the number of achievement standards (N).

The analysis confirmed a two-track design in which the four core subject domains (Matter, Motion and Energy, Life, Earth and Space) and the newly established 'Science and Society' domain follow divergent developmental pathways. This two-track design aligns with international science education discourses advocating for the parallel development of

an academic-centered pathway, which deepens conceptual understanding, and a citizenship-centered pathway, which connects scientific knowledge to social decision-making and practice (Bencze & Carter, 2011; Hancock et al., 2019; Hodson, 2011).

First, the four core domains exhibit a qualitative leap from "sensitivity"-centered education at the elementary level to "aesthetic"-centered education at the secondary level. In particular, the domains of Life and Earth showed very high levels of "sensitivity" at 53.3% and 70.0%, respectively, in the elementary 3rd–4th grade cluster, emphasizing an emotional bond with nature. However, at the middle school level, "aesthetic value" surged to approximately 70–88% across all four domains. This indicates a pursuit toward establishing a "scientific worldview" that discovers universal laws and logical order behind phenomena and experiences intellectual joy.

Second, the "Science and Society" domain demonstrates a unique evolutionary path for cultivating "scientific citizenship". The overwhelmingly high proportion of "3-1. Contribution to a Safe and Sustainable Society" (66.7%–80.0%) at the elementary level is because it corresponds to the foundational stage of ecological transition education, which emphasizes individual and normative practices such as water conservation and environmental protection. The emphasis on sustainability-related practices in elementary stages is consistent with the international consensus that fostering early sensitivity and a will to act regarding environmental and safety issues forms the basis for subsequent civic competencies (OECD, 2021; UNESCO, 2017). However, at the middle school level, "3-2. Enjoying Scientific Culture" (71.4%) and "1-3. Scientific Usefulness" (57.1%) rise rapidly, replacing "3-1. Contribution to a Safe and Sustainable Society". This proves that the concept of citizenship is becoming more sophisticated, moving beyond simple practice toward "active and communicative citizenship", where students independently make decisions in connection with their career paths while discussing and communicating with others based on scientific data (Levinson, 2013).

Third, a differentiated approach based on domain specificity was also identified. The "Motion and Energy" domain consistently emphasized "usefulness" (50–60%) across all grades, highlighting the engineering application of scientific principles, whereas the "Matter" domain emphasized "ethics" (17.4%) at the middle school level compared to other domains, strengthening the accountability of experimental science. This suggests that science education is establishing optimal affective goals that align with the Nature of Science (NOS) of each domain.

Conclusion and Suggestions

Conclusion

This study longitudinally analyzed the distribution characteristics of "Values and Attitudes" embedded in the achievement standards of the 2022 Revised Common Science Curriculum (Grades 3-9) from the cross-sectional perspectives of school level and subject domain. The results confirmed that the new curriculum builds a very systematic and differentiated 'Affective Developmental Pathway' considering students' cognitive development and the nature of the subject.

First, as the school level increases, the center of gravity of affective goals undergoes a qualitative transition from 'Emotion' to 'Reason'. In the concrete operational stage (Elementary Grades 3-4), "(1-4) Sensitivity" is emphasized

to focus on forming interest but in the middle school stage, '(1-1) Aesthetic Value' surges to over 80% in the four core domains, aiming to establish a 'Scientific Worldview'.

Second, the 'Science and Society' domain shows a unique evolutionary pathway for fostering 'Citizenship'. It expands from '(3-1) Contribution to a Sustainable Society' in the elementary stage to '(3-2) Enjoyment of Science Culture' and '(1-3) Usefulness' in the middle school stage, advancing into 'Active and Communicative Citizenship'.

Third, tailored affective goals were designed according to the characteristics of each subject domain. The 'Motion and Energy' domain emphasized 'Usefulness' across all grades, highlighting engineering applications, and the 'Matter' domain emphasized 'Ethics (Safety)' in the middle school stage, highlighting the accountability of experimental science.

This study focused on analyzing the distribution and developmental characteristics of "Values and Attitudes" embedded in the achievement standards of the 2022 Revised Science Common Curriculum; however, a direct comparative analysis with previous curricula was not included within the research scope. Nevertheless, to more clearly understand the nature of the shift in the 2022 Revised Curriculum—where "Attitudes" were expanded into "Values and Attitudes"—follow-up research comparing and analyzing these with the achievement standards of previous curricula, such as the 2015 Revised Curriculum, is necessary. Such comparative studies would enable a curricular interpretation of whether the qualitative changes in the "Values and Attitudes" category represent a "discontinuous innovation" or a "gradual deepening along a continuum". Furthermore, they could provide more specific implications for the future direction of science curriculum improvement and the design of the affective domain.

Educational Implications

Based on the conclusions above, the following suggestions are made for the successful implementation of the 2022 Revised Curriculum.

First, bifurcated instructional strategies that consider the characteristics of grade levels and subject domains are needed and subject domains. Elementary school teachers should focus on observation- and experience-centered lessons that can stimulate students' "sensitivity". In contrast, middle school teachers should parallel principle-centered lessons that allow students to experience "aesthetic joy" in the four core domains with discussion-centered lessons in the "Science and Society" domain.

Second, textbooks must faithfully reflect the affective developmental trajectory of the achievement standards. Elementary school textbooks should feature rich visual materials, while middle school textbooks should provide a balanced arrangement of materials demonstrating the logic of scientific principles and reading materials addressing social issues.

Third, an improvement in the assessment system for the affective domain is required. As revealed in this study, since the emphasized values vary by grade level and domain, it is necessary to develop diversified assessment tools that reflect the specificity of each domain.

Conflict of Interests

The authors declare no conflicts of interest.

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