TABLE V
QUESTIONS ON CT PROCESS

AP Process Competency score	Questions 1 2 3 4 5	Computational thinking
AP1.	Is the learner able to identify problems in real life and clearly describe the problems needed to be resolved?	Abstraction (extraction of key elements) Abstraction (Decomposition) Abstraction (Algorithm) Abstraction (Modeling)
	Can the learner identify the key elements to solve the problem and decompose them into solvable units?	
	Is the learner able to structure and articulate ideas for solving the problem?	
	Can the learner select a suitable AI model for solving the problem?	
AP2~3.	Can the learner collect and store the data appropriate for problem-solving and AI model training?	Data collection Data structure development Data analysis
	Is the collected data systematically structured and stored?	
	Is the learner collecting data for AI training by dividing it into training and test data?	
	Is the learner considering the quantity of data?	
	Is the learner considering the quality of data?	
AP4.	Is the learner able to assign labels, key attributes, and predictive attributes suitable for problem-solving based on an understanding of the principles of AI models?	Abstraction (extraction of key elements) Automation (Simulation)
	When testing an AI model, is the learner performing the tests in consideration of many different aspects?	
	To improve the model's accuracy, is the learner able to modify, add or supplement the data or adjust the training conditions (epochs, batch size, learning rate, ratio of validation data) as necessary?	
AP5.	Can the learner implement a program using control structures, calls, variables, and operators without logical errors?	Automation (Coding) Automation (Simulation)
	Can the learner implement a program that receives data as input and produces the desired output values?	
	Is the AI model being used in the right context?	
	Can the learner identify the cause of an error and take corrective actions?	
AP6.	In implementing the program, has the learner considered exceptional cases?	Generalization
	Has the learner considered the stability of the completed program?	
Reflection	In the problem-solving process, have the roles been properly delegated, and have the assigned tasks been performed to fulfill the project's aims?	Sharing and collaboration
	Can the members share their ideas and opinions for problem-solving and communicate continuously?	
	Can the members share the results with co-workers and discuss the pros and cons accordingly?	

2) Questions of AI ethical competence In this study, AI ethical competence was evaluated by adding the scores of ethical literacy and practice execution. Ethical literacy was evaluated via pre- and post-self-diagnosis, and the evaluation of the ability of ethical practice execution involves evaluating the level of ethical practice execution in the process of the project. The ethical literacy evaluation was designed such that perception of AI ethics could be self-evaluated through pre-evaluation, and participants could develop the habit of checking the standards of AI ethics. As shown in Table 6, the evaluation items consisted of the elements of AI ethics, which are the core values of AI (social influence), diversity and bias exclusion, algorithm transparency, privacy, and accountability and publicity.

TABLE VI
PRE/POST QUESTIONS ON AI ETHICAL LITERACY

No	Areas of AI Ethics	Questions
	Ethical literacy	**1 2 3 4 5**
1	Core values of AI (Social influence, Stakeholders)	AI technologies (services) must include ethical considerations.
2		AI technologies (services) are essential to human life and useful in humans leading a better life.
3		AI technologies (services) positively or negatively impact human life.
4		AI technologies (services) must respect human freedom and dignity
5		The development and use of AI technologies (services) require the participation of various groups across different generations and countries, etc

6	Diversity & Bias exclusion	When developing AI technologies (services), there should be no discrimination based on gender, race, religion, region, ethnicity, etc
7		When developing AI technologies (services), a separate, dedicated service in consideration of the socially underprivileged and the vulnerable is required
8		Use of sensitive or personal data must be minimized or prohibited.
9	Algorithm transparency	When developing an AI algorithm, it is acceptable to add hidden functions that only the developer (myself) knows.
10		Humans, not AI, must make important or final decisions.
11		The entire process, from development to use of AI technology, should be disclosed in a transparent manner without secrecy.
12	Privacy	Data used in AI technologies (services) must be disclosed to the public.
13		One must be informed of the use of data relating to oneself, and one may object to the use of the data if one does not wish to.
14		To ensure the protection of privacy, measures such as encryption and anonymization are necessary.
15	Accountability & Publicity	Responsibilities between developers, suppliers, and users of AI technologies (services) must be clearly defined
16		One should be aware of precautions such as risks that may occur in the process of using AI technologies (services).
17		It is not acceptable to waive the protection of copyrights, portrait rights, and personal information of the minority for the sake of implementation of AI technologies (services) as a service beneficial to the majority

The evaluation of the AI ethical practice execution was conducted as a process evaluation, which was applied for each step of the six-step process, as shown in Fig. 1. In general, AI ethics should be considered with computational thinking while designing and implementing an AI model to solve real-life problems. Therefore, the evaluation of AI practice ethics is structured, as shown in Table 7, such that the practice of AI ethics can be considered alongside computational thinking. The evaluation of the AI practice ethics was conducted in two ways. First, self-evaluation was conducted using questions assessing the level that AI ethics was actually practiced in the project. Second, the observational assessment was conducted by teachers and mentors through portfolios prepared for each project step.

TABLE VII
QUESTIONS ON AI ETHICAL PRACTICE EXECUTION

AP Process	Questions	Elements of AI Ethics
Level of importance Low← →High	1 2 3 4 5 □□□□□	Level of execution Low← →High
AP1. Problem Definition and Topic Selection	Have I considered what kind of influence the project will have on society after completion and planned accordingly?	Social influence
	Have I made sufficient considerations from the perspective of service users while developing AI technologies or services? (For example, consider the position of the person who should purchase and use a mask when producing a mask and aiming to improve the filter's performance.)	Stakeholders
	Does the planned project serve the public interest?	Publicity, Accountability
AP2. Data Collection	In the data collection process, have I made sure that other people's personal information is not included and data without infringement on portrait rights are collected?	Transparency, Privacy
	Have I provided an accurate indication of the use of copyright and the data source?	Privacy
	Have I desired to use copyrighted data without the copyright permission to create the desired model?	Privacy
AP3. Data Preprocessing	Do the collected data show composition with diversity without discrimination based on race, region, or gender and without intentionally ignoring these issues?	Bias, Diversity
	Have sensitive data or data that may infringe upon privacy policy been excluded during data processing?	Bias
	Is the data uniformly distributed such that no data bias may lead to discriminatory results? (For example, there may be 50 photos of women and 100 photos of men, which would reduce the probability of correctly detecting photos of women)	Diversity
	Was I unbiased towards personal tastes or preferences while collecting data?	Diversity

	Even if the training results did not produce the desired results, have the results been honestly disclosed without fabrication, or have the training data been modified and used?	Accountability, Publicity
AP4. Model Training & Evaluation	Have I performed modeling according to an honest process such as systematically sharing information?	Accountability, Transparency
	Have I understood the intention of the open-source algorithm and used it for its intended purpose?	Transparency
	Do the AI technologies (services) perform inference as intended?	Transparency
AP5. Applications Development and Their Application	Is the application I developed designed not to cause any harm to humans?	Human dignity
	Does the application I developed serve the basic purpose of pursuing human happiness?	The common good of society
	Is the trained AI model applied to the application fitting to the purpose of OO?	Fitness of the technology to the purpose
AP6. Performance evaluation and analysis	Have the roles such as users, developers, and suppliers been appropriately delegated within the team, and has the discussion been held on side effects expected from the completed service and on solutions to the expected problems?	Accountability, Publicity
	Do I believe I am obligated to disclose and rectify any unintended adverse effect in the completed service with a sense of accountability?	Accountability, Publicity

III. Results and Discussion

The evaluation of computational thinking and AI ethical competence was conducted for 18 elementary school students and 12 middle school students with experience in block code programming and AI education, including preliminary education. Computational thinking, AI ethical literacy, and AI practice ethics were evaluated and compared as evaluation items. The evaluators who participated in the evaluation consisted of two super mentors who evaluated all students and ten mentors who monitored their respective groups.

A. Comparison of computational thinking and AI ethical competence

To compare computational thinking and AI ethical competence, based on the scores of computational thinking, participants were divided into upper 30%, middle 40%, and lower 30% groups, and the scores of ethical literacy and practice execution were compared. Table 8 shows the scores for the self-evaluations of ethical practice execution, where the upper 30% and middle 40% in computational thinking scores have higher scores than those of the lower 30%. This indicates that, in the problem-solving process, a group with relatively high computational thinking tends to create a project with consideration of the societal and ethical impact or problems of AI.

TABLE VIII
COMPARISON OF COMPUTATIONAL THINKING AND ETHICAL PRACTICE EXECUTION(SELF-EVALUATION) (UNIT: POINT)

Category	Mean score of computational thinking	Self-evaluation of ethical practice execution
upper 30%	89.9	8.0
middle 40%	80.1	8.2
lower 30%	52.1	7.4

Table 9 shows the scores of the observational assessment of the portfolios performed by the mentors, and the score of the upper 30% group was 8.4 points in terms of computational thinking skills, which is significantly higher than that of the middle and lower groups. This shows that, in the problem-solving process, a group with relatively low computational thinking finds solutions for social and ethical problems that AI will have difficult and perform ethical practice and applications. In particular, for the middle group, the self-evaluation score was relatively high, but the observational assessment score was considerably low. This shows that the group has high cognitive competence for AI ethics but has limitations in the practice and application of AI ethics.

TABLE IX
COMPARISON OF COMPUTATIONAL THINKING AND ETHICAL PRACTICE EXECUTION (OBSERVATIONAL ASSESSMENT) (UNIT: POINT)

Category	Mean score of computational thinking	Observational assessment of ethical practice execution
upper 30%	89.9	8.4
middle 40%	80.1	6.9
lower 30%	62.1	6.7

Table 10 outlines the pre-and post-self-evaluations results for diagnosing AI ethical literacy. The upper and middle groups showed relatively higher AI ethical literacy in CT skills than the lower group. However, the lower group showed a better post-program improvement (0.5 points) than the upper group. The post-program ethical literacy scores were similar between the groups; upper 30% (4.7 points), middle 40% (4.5 points), and lower 30% (4.5 points). Although the result cannot be considered significant regarding the relationship between computational thinking and ethical literacy, they indicate that both domains should be considered integrated.

TABLE X
COMPARISON OF COMPUTATIONAL THINKING AND ETHICAL LITERACY
(UNIT: POINT)

Category	Mean score of computational thinking	Ethical literacy(/5)	
		Pre-evaluation test	Post-evaluation test
upper 30%	89.9	4.4	4.7
middle 40%	80.1	4.4	4.5
lower 30%	52.1	4.0	4.5

B. Computational thinking and AI ethical competence with different learning styles

In this study, for the comparative analysis of the difference between computational thinking and AI ethical competence according to the learning style, an additional test was performed on the learners' learning style. The learning style test used in this study is based on the Kolb Learning Ability Test (KLAT), which identifies and classifies an individual's learning style based on the Experiential Learning Theory from David Kolb, an educational theorist. In particular, based on Guilford's Structure of Intellect theory about human intelligence, assessments were made on the four domains of verbal comprehension, numbers, space, and drawings, allowing for the evaluation of the cognitive development of learners and understanding the characteristics of learners. As indicated by the comparison results in Table 11, the scores of CT skills were somewhat higher in learners with learning styles of experimental learning (77.2 points) and experience-based learning (76.4 points). The scores of the ability of ethical practice execution were high with learners of experimental learning (16.0 points). For ethical literacy, learners with an experience-based learning style showed a rather low score of 4.4 points. Experimental and experience-based learning prefer collaborative problem-solving and enjoy working on a project with fellow learners. As the program selected is a project-type educational methodology called Hackathon to develop CT skills, this is thought to have impacted the CT skills compared to other learning styles. In addition, because learners of experimental and theory-based learning styles learn through abstract and objective conceptualization, these learners are thought to have had higher scores for ethical practice execution and ethical literacy.

TABLE XI
COMPARISON OF COMPUTATIONAL THINKING AND ETHICAL LITERACY
(UNIT: POINT)

learning style	CT skills (/100)	Ethical practice execution (/20)	Ethical literacy (/5)
Thinking-based learning (18%)	73.9	15.4	4.7
Theory-based learning (16%)	70.7	15.4	4.7
Experimental learning (33%)	77.2	16.0	4.6
Experience-based learning (33%)	76.4	14.8	4.4

To enhance the effectiveness of the program developed in this study, the instructional design reflecting the learner's characteristics in learning was applied. Consequently, a difference in computational thinking and AI ethical competence was confirmed depending on the learner's learning style. For program operations in the future, the application of teaching and learning methods that consider the characteristics of learners are expected to produce superior educational effects.

IV. CONCLUSIONS

In this study, for the analysis of the relationship between AI ethical competence and computational thinking, an AI-integrated education program integrating AI education and AI ethics education was developed, applied to students, and performed evaluations. Concerning the indicators for evaluation, computational thinking and AI ethical competence were comprehensively evaluated across various areas, and the results were compared. The results are summarized as follows. First, the group with relatively high computational thinking skills had higher AI ethical literacy and ethical practice execution. If AI education aims to develop computational thinking, it is a thought process involving the complex interplay between cognitive, emotional, and behavioral domains. This is a reason why we consider that computational thinking and ethical competence are closely related. A correlation exists between the thought process of computational thinking and higher-order cognitive and emotional activities such as ethical competence.

Therefore, this study aimed to examine and analyze the relationship between the two. Second, a significant difference was observed in the self-evaluations on the ability of ethical practice execution (8.2 points) and observational assessment of the same (6.9 points) in the middle group on computational thinking. This shows that, although the middle group of computational thinking has a cognitive consideration of AI ethics, the group does not apply or practice AI ethics in real life as much as their knowledge of AI ethics. Third, through additional analysis, significant differences were confirmed between computational thinking skills and ethical competence depending on the learning styles

Suggestions based on the findings of this study are presented as follows. First, AI ethical competence is not simply about knowledge acquisition. AI education should help design and implement problem-solving strategies and methods considering AI's social and ethical impact in actual problem-solving processes. Second, research on computational thinking and AI ethical competence should be further promoted for more accurate comparative analyses between computational thinking and AI ethical competence. Third, to increase the effectiveness of the AI-Integrated Education Program, developing a mid-to-long-term program rather than a short-term education program is necessary, as well as the systematic establishment of an observational assessment and portfolio evaluation such that more systematic process-focused evaluations can be conducted.

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