JOIV : Int. J. Inform. Visualization, 6(2-2): A New Frontier in Informatics - August 2022 506-515

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage : www.joiv.org/index.php/joiv

Analysis of AI Ethical Competence to Computational Thinking

Jinah Bae [a,c], Junghun Lee [a,c], Jungwon Cho [b,c,*]

[a] Major in Computer Education, Graduate School, Jeju National University, 102 Jejudaehak-ro, Jeju 63243, Republic of Korea
[b] Department of Computer Education, Jeju National University, 102 Jejudaehak-ro, Jeju 63243, Republic of Korea
[c] Intelligent Software Education Research Institute, Jeju National University, 102 Jejudaehak-ro, Jeju 63243, Republic of Korea
Corresponding author: *jwcho@jejunu.ac.kr

***Abstract*— Artificial Intelligence (AI) is a driving force leading the intelligent information society. Major advanced countries have established AI into key policy projects and made continuous efforts to nurture and develop future talents through AI education. Unlike conventional software, AI can infer results through training with data, and if there is a data bias, it may cause social and ethical problems. These problems incur extensive damage to society, so ethical consideration is essential in terms of effectiveness and efficiency in implementing AI. Computational thinking aims to perform effective and efficient problem-solving to address real-life problems using computing technology such as AI. Therefore, ethical considerations in AI education can be regarded as an important element of computational thinking. This study aims to analyze the relationship between computational thinking and AI ethical competence from problem-solving using AI. To this end, evaluations and analyses of computational thinking and AI ethical competence were performed based on the evaluation results of the education program with the integration of AI and AI ethics. The analysis demonstrated that the group with relatively high computational thinking skills also showed high AI ethical competence. The findings of this study are expected to facilitate research on nurturing computational thinking through AI-integrated education with sufficient consideration of AI ethics. To increase the effectiveness of the AI-integrated education program, it is necessary to develop a mid-to-long-term education program to systematically examine the process-focused evaluation by systematizing observational and portfolio assessments.**

Keywords— AI education; AI ethics education; computational thinking; AI integrated education model; AI ethical competence.

Manuscript received 15 Oct. 2021; revised 9 Feb. 2022; accepted 12 Apr. 2022. Date of publication 31 Aug. 2022.

I. INTRODUCTION

With the combined effects of the intelligent information society and COVID-19 pandemic, artificial intelligence (AI), big data, and metaverse have garnered attention as core technologies worldwide. Among these technologies, AI is a key driving force leading the intelligent information society by solving complex problems in our society and improving the quality of human life. Accordingly, major countries such as the United States and China have made active investments to gain competitive edges in AI technology and compete for establishing national AI strategies to foster and develop AI talents as key policy projects. In line with the global trend, the South Korean government has announced the 'National AI Strategy' encompassing future strategies for the AI era across different ministries and presented the goal of cultivating AI literacy for the Korean public. In particular, AI education has been promoted in the curriculums of elementary and secondary schools to develop future talents in this field [1].

AI education aims to develop 1) AI literacy for understanding the societal impact of AI and proper use of AI and 2) computational thinking that enables effective and efficient problem-solving for real-life problems using AI. Unlike conventional software, AI can infer results through training with data. However, bias in data that arise in this process may lead to unexpected consequences or distorted results. This characteristic of AI makes predicting results difficult, leading to the risk of deriving results not designed or intended by the developer [2]. Representative examples include Tay, an AI chatterbot by Microsoft [3], which caused controversies because of racist messages released owing to data bias, and the AI recruiting engine from Amazon, which caused problems in transparency, fairness, and credibility [4]. These ethical and social issues considerably damaged each corporation. If we view the problem in terms of effectiveness and efficiency, the ethical considerations involved can be regarded as important elements of computational thinking. Computational thinking is the ultimate goal and core competency of AI education. Computational thinking aims to discover solutions to problems through heuristic reasoning. It requires designing plans and involves considering possible errors or side effects in the presence of uncertainties [5].

Considering both technical errors and the consequent societal impact and ethical problems is necessary for problem-solving with computational thinking. People with high computational thinking skills are likelier to consider AI's societal and ethical impact comprehensively. Therefore, in this study, we aim to design and apply an AI-integrated evaluation model for the evaluation of computational thinking and AI ethical competence, as well as examine and analyze the relationship between computational thinking and AI ethical competence.

In this study, as the theoretical background necessary for analyzing the relationship between computational thinking and AI ethical competence, we first examine the prior related research on AI ethics education, computational thinking, AI ethical competence, and learning styles of the learners to present the research methodology and major content of this study.

II. Materials and Method

A. AI Ethics Education

With the advancements in AI technology, a social interest in the cultivation and development of AI literacy and computational thinking has been rising, and AI ethics are also drawing more attention. AI ethical competence is the competence of citizens who use AI, policymakers related to AI, and all members of society who are not AI experts but use AI and are affected by AI in some manner [6]. Accordingly, several major countries, including the United States and China, have emphasized AI ethics and education.

The US has proposed '5 Big Ideas (perception, presentation and reasoning, learning, natural interaction, societal impact)' for the AI education of students from kindergarten to 12th grade (K-12) through the AI4K12 initiative. This initiative covers the topic of AI ethics in the section named 'Consideration of Social and Ethical Implications of AI System Development' [4].

In 2017, China announced the New Generation Artificial Intelligence Development Plan, aiming to position itself as a world leader in all fields of AI by 2030. In 2018, AI textbooks were developed to promote general AI education through the entire lifecycle of students, from kindergarten to elementary, middle, and high school, and up to vocational education. In 2019, the basic framework of AI education was presented through the Beijing Consensus on Artificial Intelligence and Education. The New Generation Artificial Intelligence Development Plan emphasizes that the ethical issues of AI should be fully considered in the process of designing and implementing a curriculum for AI education [7].

In South Korea, AI education and ethics are emphasized through the 2022 Revised National Curriculum General Guidelines Highlights, and in the 'Elementary and Secondary AI Education Curricula' published by the Ministry of Education and Foundation for the Advancement of Science and Creativity in 2020, the section 'Societal Impact of AI' discusses AI ethics. Table 1 outlines the main content of AI ethics education by school age. Examining the content of AI education curricula at home and abroad, an increasing emphasis on AI ethics education and general AI education is observed.

TABLE I
Main elements in the content of AI ethics education in elementary/middle/high school curriculums in South Korea

Grade	Areas and content	
Elementary School Basic (Grades 1-4)	AI influence	AI, our helpful friend
Elementary School Advanced (Grades 5-6)	AI influence	Life with AI
	AI ethics	Proper use of AI
Middle School	AI influence	AI and my occupation
	AI ethics	Prevention of misuse/abuse of AI
High School Basic	AI influence	Social problem solving
		Data bias
	AI ethics	Moral dilemma
		Social accountability and equity
High School Advanced	AI influence	Harmonious coexistence with AI
		Algorithm bias
	AI ethics	Ethics of AI developers
		Ethics of AI decision-makers

However, current content is primarily focused on the transfer of knowledge about AI ethics, and directly discussing AI ethics is impossible in the real problem-solving process. Preventing social and ethical problems caused by AI technology is difficult with the existing AI ethics education centered on delivering knowledge. AI ethics should not be learned in terms of simple knowledge acquisition but implemented in daily life through actions and practice [8]. That is, AI ethical competence and computational thinking can be enhanced by considering the elements of AI ethics while designing and implementing AI models to solve real-life problems

B. Computational Thinking and AI Ethics

According to 'Computing Curricula 2020' which presents the current status of computing education and curriculum guidelines, AI is included in the domain of computer and data science knowledge [9]. Therefore, the goal of AI education can be considered as the cultivation of computational thinking, which is the same as the goal of existing computing education. Wing first defined 'computational thinking as thinking like a computer scientist to solve problems when one faces a problem to be solved' [10]. Later, in 2010, computational thinking was defined as 'a thought process involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent' [11]. Research on teaching and learning the methods, content, and evaluation for AI education should begin based on computational thinking, which can be considered as the underlying thought process and problem-solving method of computer education, and the approach of AI education should consider the entire context of computer education [12]. Data-based computer modeling abilities in unsupervised learning and reinforcement learning used in AI can be enhanced through humans' problem-solving processes, and this is computational thinking [13].

Simply put, AI education should be conducted to develop computational thinking skills, and computational thinking is a thought process for effective and efficient problem-solving for problems encountered in real life using computing such as

AI. This indicates that AI education should be conducted not only for the improvement of cognitive competence for effective and efficient solving of real-life problems but also for affective competence that considers the societal and ethical impact that AI has on real life. In addition, the recent development and dissemination of AI have caused unanticipated side effects; thus, when designing a problem-solving model through computational thinking, technical and procedural errors must be considered alongside the ethical side effects and societal impact. This implies that a close correlation exists between computational thinking and AI ethics.

Activities that require computational thinking must entail the integration of human higher-order reasoning and cognitive and emotional approaches. In AI education, activities that cultivate and develop computational thinking abilities will nurture a sense of ethics through real-life problem solving as well as cognitive reasoning. Emotional thinking is necessary for the development of computational thinking, and that emotional thinking is necessary for moral decision-making and is required when reasoning through rational evidence [14]. That is, to promote computational thinking, cognitive activities and activities for enhancing emotional regulation, emotional thinking, and moral consciousness are required. The process of resolving information ethics problems by incorporating a moral thought process develops the cognitive ability for information ethics and affective ability to practice, helps solve problems of information ethics and promotes computational thinking [15]. Enhancing students' logical reasoning is needed to promote computational thinking, which requires humanistic approaches as well as the approaches of computing disciplines. In addition, he argued that in the process of solving moral dilemmas, learners could experience educational schemas in abstract thinking through symbols, problem-solving, and decision-making via computational thinking [16]. These studies indicate that a correlation exists between computational thinking and AI ethical competence. In this study, for the analysis of the relationship between computational thinking and AI ethical competence, the AI education-integrated model combining existing AI education and AI ethics education is applied for the evaluation of computational thinking and AI ethical competence of learners, thereby analyzing AI ethical competence in relation to computational thinking.

C. Learning Style

AI education aims to cultivate computational thinking skills. To implement effective education to develop competencies in computational thinking, understanding the learning patterns of how learners perceive and process information is necessary. In this respect, Kolb argued that understanding students' preferred learning styles and employing the preferred teaching and learning strategies in different learning environments is important. Therefore, this study aims to understand learners' learning styles for developing a more effective AI education program and to verify the effectiveness of the developed program. To this end, a learning style test was conducted, which is a reconstruction of the Kolb Learning Ability Test adapted for Korean elementary and middle school students. Learning styles are classified into experience-based, thinking-based, experimental, and theory-based learning. The test was conducted for students who participated before the start of the program.

D. Research Method

This study analyzes AI ethical competence in relation to computational thinking based on the AI education-integrated evaluation model that presented a real-life problem and was designed to solve problems effectively. For this purpose, as shown in Table 3, the AI evaluation program was conducted in four steps. In the 1st step, previous studies on the evaluation of computational thinking and AI ethical competence were analyzed. In this process, the elements for the evaluation of learners' computational thinking and that of AI ethical competence were extracted to be used as indicators for evaluation. In the 2nd step, the AI-Integrated Education Program was developed to evaluate computational thinking and AI ethical competence, as shown in Table 2.

TABLE II
AI-INTEGRATED EVALUATION PROGRAM

Step		Main theme	Activities
Preliminary education		Understanding of AI	Pre diagnosis of AI ethics Test of learning style Basic education on AI
AP1	Problem Definition and Topic Selection	Identifying problems based on proposed keywords and selecting project topics with a focus on solutions to the identified problems	Hold a brainstorming session on the problems that caused difficulties or inconvenience in everyday life, with relevance to the common keywords Converge on one problem that members think commonly applicable or important Select a topic and discuss specific solutions Select a training model appropriate for problem-solving Attach stickers to AI ethics elements considered in Step 1
			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
AP2	Data Collection	Selecting a training model suitable for a project topic and performing data collection	Select an appropriate data type to be used for selected training model Check the sources and route of data collection Data collection Attach stickers to AI ethics elements considered in Step 2

			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
AP3	Data Preprocessing	Preprocessing the collected data suitable for training	Examine the collected data (data quantity, classified groups, source, etc.) Perform preprocessing of collected data into a format suitable for training Attach stickers to AI ethics elements considered in Step 3
			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
AP4	Model Training and Test	Model training with processed data, and proceeding to the previous or next step according to the inference/prediction provided by the training	Proceed with training using the preprocessed data Test the created model after training Examine the inference results and check the accuracy of the inference result If the accuracy of the inference result is low, move back to AP3 If the accuracy of the inference result is within a normal range, proceed to AP5 Attach stickers to AI ethics elements considered in Step 4
			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
AP5	Application Development & Application	Application development using the model created in the previous step and applying the problem-solving method presented in AP1	Use the AI model trained in AP4 Program the application with a focus on the topic selected in AP1 Apply the AI model to the application program and perform testing Attach stickers to AI ethics elements considered in Step 5
			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
AP6	Performance Evaluation & Analysis/ Model tuning	Evaluation and analysis on the performance of the training model and applications	Depending on the errors generated, move back to the previous steps Discuss the utilization methods of the final project in real life Attach stickers to AI ethics elements considered in Step 6
			Diagnosis of AI practice ethics
			CT skills diagnosis: observational assessment by one mentor and two super mentors
Project Reflection		Reflection on all activities and preparing materials for sharing	Writing of reflection journals Preparing materials for sharing Post-evaluation of AI ethics
Project Sharing		Project preparation	Present the prepared materials and hold a feedback session

The AI-Integrated Education Program was designed to evaluate computational thinking and AI ethical competence demonstrated through AI education and real-life problem solving using various methods such as observational assessment, self-evaluation, and portfolio evaluation. The 3rd step was program operation, which was divided into preliminary education and the problem-solving program. Preliminary education was conducted to reduce the gaps concerning knowledge levels on AI and to smoothen the operation of the education program, and the problem-solving program was designed to solve real-life problems using AI. Finally, in the 4th step, evaluation results were compared to analyze the relationship between computational thinking skills and AI ethical competence.

TABLE III
AI-INTEGRATED EVALUATION PROGRAM RESEARCH METHOD

Step	Process	Research procedure and method	Products
1	Analysis of prior research	• Analysis of prior studies on computational thinking (CT) evaluation • Analysis of prior studies on AI ethics evaluation	• CT evaluation indicators • AI ethics evaluation indicators
2	Evaluation program development	• Development of questions for the assessment of ethical literacy and execution • Development of questions on process for computational thinking evaluation • Development of AI-integrated evaluation program	• Evaluation method • Questions • AI ethics-integrated evaluation program
3	Program operation	• Operation of AI-integrated evaluation program • Evaluation of learning style, computational thinking, and AI ethical competence	Program operation
4	Result analysis	• Analysis of relationship between computational thinking and AI ethical competence	Results of comparative analysis

E. Evaluation of Computational Thinking and AI Ethical Competence

Thirty students participated in the education program, consisting of 18 elementary school students and 12 middle school students, and the evaluation method was designed as outlined in Table 4. To test their perception on AI ethics, pre- and post-program evaluations were conducted. In addition, during the main education program, the importance level of AI ethics and execution level of AI practice were assessed for each step of the problem-solving process. To asses, computational thinking, three mentors (in charge of observational assessment) made observations in each step and conducted a process evaluation.

TABLE IV
EVALUATION METHOD

Evaluation and diagnosis	Preliminary education	Main program						
		AP1	AP2	AP3	AP4	AP5	AP6	Reflection
Learning style test	O							
AI ethical literacy	O							O
AI ethical practice execution		O	O	O	O	O	O	
CT skills diagnosis (Observational assessment by mentors)		O	O	O	O	O	O	O

1) Questions of CT skills process evaluation

Computational thinking refers to thinking towards effective and efficient problem-solving faced in real life using computing such as AI. Because solving real problems using the principles of computer science is a skill, conducting evaluations of computational thinking using process-focused evaluations during the problem-solving process is advisable. Process-focused evaluation is a comprehensive evaluation method for leveraging and applying the acquired knowledge in problematic situations encountered in real life [17]. In this study, to evaluate computational thinking using the method of process-focused evaluation, the data preprocessing, application development, and debugging steps were added to the existing computational thinking-based problem-solving process [18]. Therefore, the entire process comprises six steps, as shown in Fig. 1.

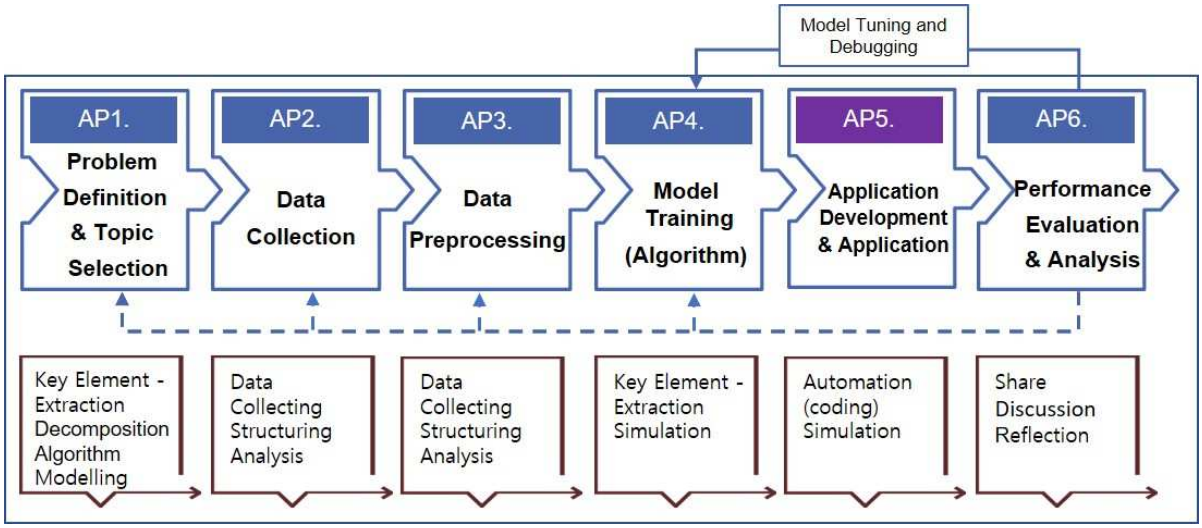

Fig. 1 Problem-solving process based on computational thinking

The 1st step is 'Problem Definition and Topic Selection.' In this step, the problem to be solved in real-life problem situations and goals are clearly defined, and the key elements are identified to decompose the problem and abstraction. Based on the problem, the AI model is selected accordingly. In the 2nd step, 'Data Collection,' data required for problem-solving, training data for the AI training and test datasets are prepared. The 3rd step is 'Data Preprocessing' in which whether the quantity and quality of data are considered appropriately is determined, and the collected data are processed. The 4th step is 'Model Training & Evaluation,' in which the AI is trained with the prepared data. Learners can modify, add, supplement the data or adjust training conditions to improve the accuracy of the AI model. The 5th step is 'Application Development and Application,' in which the AI model completed with the training is used for programming. The 6th step is 'Performance Evaluation and Analysis,' in which reflection is performed on stability, handling exceptions, and the overall process for problem-solving.

The evaluation of computational thinking in the problem-solving process was conducted based on the observational assessment of three mentors. As presented in Table 5, questions for observational assessment were prepared for evaluation based on comprehensive observation not only for the cognitive domain but also for the attitude and affective domains by observing learners' performance in each step of the problem-solving process.

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.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea(NRF-2021S1A5C2A04088646)

REFERENCES

[1] Ministry of Science and ICT 2019, National Artificial Intelligence Strategy. Ministry of Science and ICT.

[2] J. Bae, J. Lee, and J. Cho, "An Artificial Intelligence Ethics Education Model for Practical Power Strength," *Journal of Industrial Convergence*, vol. 20, no. 5, pp. 83–92, May 2022, doi: 10.22678/jic.2022.20.5.083.

[3] S. H. Han, "Social and Ethical Issues of Artificial Intelligence Technology," *J. Korea Multimedia Soc*., vol. 20, no. 3, pp. 41–52.

[4] S. J. Jang et al[1]., "A Study on Exploring the Contents of Artificial Intelligence Ethics Education in Elementary and Secondary Schools SIGs 2021," 2022.

[5] Graduate School of Literature and Future Strategy, "KAIST Graduate School of Literature and Future Strategy - Ph.D." *futures.kaist.ac.kr*. https://futures.kaist.ac.kr/en/?c=290&s=&gp=1&gbn=viewok&ix=2900 (accessed Aug. 18, 2022).

[6] T. Kim and S. Byun, "A Study on the Necessity and Content Composition of AI Ethics Education," *Journal of AI Humanities*, vol. 8, pp. 71–104, Aug. 2021, doi: 10.46397/jaih.8.4.

[7] D. Park, S. W. Kim, E. L. Han, C. S. Kim, C. W. Lee et al., "A Study on China's New Technology Talent Nurturing Policy in the Era of the Fourth Industrial Revolution: Focusing on Elementary, Middle, and High School-Level AI Education.". Collaborative Research Series in Comprehensive Research on China by Economics, Humanities, and Social Research Society 20-91-04, 2022.

[8] M. H. Lee., "Development and Application of a Teaching and Learning Model Integrating," KNUE Univ, Cheongju, 2008.

[9] H. S. H.S.Kim, J.H.Song and J.Y.Lee, "Direction of K-12 SW·AI Education through Computing Curricula 2020," 2020.

[10] J. M. Wing, "Computational thinking," *Commun. ACM*, vol. 49, no. 3, pp. 33–35, 2006.

[11] J. M. Wing, "Computational thinking: What and why," in *Presentation slides from Trippel Helix Conference on Computational Thinking and Digital Competencies in Primary and Secondary Education Stockholm, Sweden. https://pdfs. semanticscholar. org/presentation/d20a/a49744877f2bb98d6ad303742be7bd025fcd. pdf*, 2017, pp. 1378800312–1580695435.

[12] S. Shin, "Designing the Framework of Evaluation on Learner's Cognitive Skill for Artificial Intelligence Education through Computational Thinking," *Journal of The Korean Association of Information Education*, vol. 24, no. 1, pp. 59–69, Feb. 2020, doi: 10.14352/jkaie.2020.24.1.59.

[13] M. Oldridge, "Is it about coding? No. It's about computational thinking." 2017.

[14] M. J. Lee, "Development of Instructional Design Principles Promoting Emotional Regulation for Enhancing Computational Thinking," Education Engineering Major of Sejong University Graduate School of Education, 2020.

[15] Y. Choi and T. Lee, "A Study on the Practical Teaching of Elementary Software Convergence Education for Effective Develop of Communication Ethics conciousness and Computational Thinking," in *Proceedings of the Korean Society of Computer Information Conference*, 2018, pp. 411–414.

[16] A. M. Seoane-Pardo, "Computational thinking beyond STEM," *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality*, Nov. 2016, doi: 10.1145/3012430.3012494.

[17] J. Lim and W. Choi, "A study on characteristics and meanings of'process-focused evaluation'in the free semester program," *J. Korean Educ.*, vol. 45, no. 3, pp. 31–59, 2018.

[18] J. Lee and J. Cho, "Process-oriented Evaluation Method for Computational Thinking," *J. Digit. Converg.*, vol. 19, no. 10, pp. 95–104, 2021.