An Approach to the Utilization of Design Thinking in Artificial Intelligence Education

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***Abstract*— As artificial intelligence (AI) continues its rapid and relentless progression, the necessity for a comprehensive AI education has become increasingly evident. While South Korea has initiated various policies related to AI education, recent research has underscored the potential adverse repercussions of current instructional approaches on learners. In response to this pressing concern, the present study delves into integrating design thinking principles into AI education and meticulously assesses its impact on learning outcomes. To achieve this objective, we seamlessly amalgamated design thinking principles with AI problem-solving techniques, developing a tailor-made AI education curriculum explicitly crafted for middle school students. Subsequently, this innovative curriculum was implemented among middle school students, and their Computational Thinking (CT) competence was rigorously evaluated. The findings unequivocally establish that the infusion of design thinking into AI education significantly augmented the CT skills of the participating students. In comparison to the control group, it was discerned that middle school students who underwent AI education integrated with design thinking exhibited a statistically substantial enhancement in their Computational Thinking (CT) proficiencies. This study furnishes compelling empirical evidence that unequivocally endorses design thinking as a potent instructional approach within the domain of AI education, particularly for middle school students. Furthermore, it underscores the necessity of embracing innovative pedagogical methodologies in AI education to equip the younger generation with the indispensable skills to adeptly navigate the perpetually evolving landscape of an AI-driven future.**

***Keywords*— Design thinking; artificial intelligence education; computational thinking; middle school student; computing education.**

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I. INTRODUCTION

The beginning of the Fourth Industrial Revolution has significantly increased the volume of generated data and information. Consequently, there has been a growing reliance on data analysis methods to address complex problems. Technologies such as artificial intelligence (AI) and big data are experiencing increased utilization as they provide means to analyze data for effective problem-solving. AI has gained considerable attention as a transformative technology capable of reshaping society and daily life, owing to algorithm advancements and their application across various domains [1], [2].

It is common to perceive AI as a universal problem-solving tool that can address any challenge. AI excels at tasks such as extracting answers from structured data, performing repetitive operations, and deriving problem-solving approaches based on provided information [2]. Conversely, human capabilities, such as creativity, emotional intelligence, social interaction, and contextual understanding, remain superior to AI in many areas. Recognizing this, it becomes crucial to identify the respective strengths of AI and humans and harness them synergistically to address problems [3], [4].

Considering this, the concept of problem-solving through design thinking has gained prominence in the era of AI. Design thinking emphasizes a collaborative approach that integrates the unique strengths of both AI and human capabilities. By leveraging the problem-solving methodologies of design thinking, the analytical power of AI can be effectively combined with the creative and social intelligence of humans. This approach enables the navigation of future society by fostering collaboration and coexistence between humans and AI, leading to more comprehensive and innovative solutions. [2], [5].

Design thinking is a problem-solving method widely employed in management to comprehensively analyze the nature of a problem and derive practical solutions to address it. In this study, the following sequential steps were adopted: “empathize” to gain a deep understanding of the problem, “define” to formulate a precise problem statement, “ideate” to generate innovative ideas for resolving the problem, and “prototype” and “test” to evaluate the effectiveness of the solution by considering the feasibility of problem resolution and previously unaccounted factors. Design thinking represents a non-linear process wherein the five stages (empathize, define, ideate, prototype, test) are iteratively employed to solve problems [5]–[8]. While design thinking has garnered attention due to its emphasis on problem-solving through empathetic engagement with relevant stakeholders, it is acknowledged that sustaining the derived problem solutions poses certain limitations [7]–[9].

AI excels at executing repetitive tasks within controlled environments and extracting information from structured data. However, it encounters limitations when confronted with social and emotional predicaments [2], [5]. Design thinking offers a means to address these weaknesses. During the empathy phase, design thinking collects diverse information regarding the problem in a human-centered manner. Personas, for instance, enables the acquisition of problem-related insights from the perspective of individuals experiencing the issue, facilitating an emotionally informed approach [10], [11]. Consequently, employing design thinking in conjunction with AI for problem-solving purposes allows for the utilization of both human strengths and AI capabilities to effectively tackle challenges [11]–[14].

The Republic of Korea has recently introduced a revised curriculum for 2022 that includes AI education with a specific focus on fostering digital AI skills [15]. Consequently, the significance of AI education has grown, prompting research endeavors to explore effective methods of teaching AI to students [2], [5], [16]–[18]. Prior studies have indicated that the prevailing AI education primarily concentrates on AI principles and concepts, resulting in unfavorable perceptions and attitudes toward AI [19]–[23]. Hence, it becomes imperative to provide students with opportunities to engage with various real-life AI applications during the teaching and learning process of AI education, enabling them to comprehend the potential for problem-solving through AI [19], [20]. By incorporating design thinking into AI education, students can understand the problem-solving processes prevalent in society, while also experiencing collaborative problem-solving involving both AI and human participants. Such a pedagogical approach addresses the challenges inherent in current AI education and cultivates learners’ ability to collaborate with AI [14] effectively. So, the revised 2022 curriculum includes adopting design thinking as a teaching and learning methodology [15].

Design thinking has emerged as a valuable approach for addressing social challenges, and integrating AI into the problem-solving process of design thinking presents an efficient avenue for problem resolution. However, certain considerations must be considered in the realm of AI education. Given that design thinking was not originally devised for AI education, a misalignment exists between the problem-solving process and AI implementation. Hence, further research is warranted to enhance design thinking to align it with the problem-solving process of AI. In this study, a design thinking teaching-learning framework tailored for AI education in the context of Korea is proposed and evaluated to determine the effectiveness of AI education implemented within this framework. The primary objective of this research is to explore the potential of design thinking in AI education and assess its educational outcomes.

II. Materials and Methods

A. Materials

The general process of AI problem-solving involves collecting data, preprocessing the collected data, and visualizing the preprocessed data to derive a solution for the problem at hand. Once a suitable solution is identified, statistical methods or AI algorithms are chosen and applied to address the problem. Finally, the developed AI program is evaluated to assess its effectiveness in resolving the problem [7], [8], [10], [11].

Design thinking comprises the sequential stages of empathizing, defining, ideating, prototyping, and testing, which are repeated as necessary to solve a problem [10], [11]. Design thinking is recognized as an effective teaching and learning methodology in AI education [15]. Therefore, design thinking can be employed in the context of AI education, but it is crucial to align its application with the problem-solving processes of AI. Notably, design thinking analyzes problems by gathering data from the perspective of individuals experiencing the problem during the empathy stage, fostering empathetic and emotionally informed understanding. In contrast to AI, design thinking leverages human strengths to tackle problems [2], [5], [10], [11], [14]. However, to apply design thinking to problem-solving with AI, certain adjustments may be necessary to supplement specific content accordingly.

The initial step, empathizing, involves placing the person at the center of the problem and examining it from a human perspective. This stage involves conducting interviews, making observations, creating personas, and employing other techniques to gain insights into the problem from a human standpoint. To address problems using AI, it is crucial to identify the types of data that are relevant to the problem. This serves as the foundational information necessary for subsequent problem-solving endeavors [2], [5], [10], [11].

The defining step entails describing the essence of the problem based on observations or interviews conducted during the empathize stage. The objective is to discern the most central and fundamental problem amid the information gathered. During the problem definition stage, assessing whether the defined problem is suitable for AI utilization and whether it can be effectively solved using AI is necessary. If the problem is not amenable to AI-based solutions or if utilizing AI is deemed inefficient, it becomes imperative to explore alternative approaches. Additionally, if it is determined that an AI-driven problem-solving process is warranted, data preprocessing and visualization are essential. In the ideation phase, cleaning, preprocessing, and visualizing the data are necessary to explore practical solutions to the problem using AI. Thus, within the defined stage, it becomes crucial to determine the feasibility of AI utilization and undertake the requisite preprocessing steps to leverage AI effectively [2], [5], [10], [11].

The third stage—ideate—involves generating diverse ideas and employing techniques such as connection, combination, transformation, and modification to arrive at the most optimal idea. Within this stage, it is crucial to design an AI model that aligns with the data analysis or problem-solving objectives established based on the outcomes of data visualization. At this juncture, envisioning the problem-solving process using AI grounded in the available data is essential [2], [5], [10], [11].

Moving on to the fourth stage—prototype—the objective is to create a tangible and observable model. Through this stage, previously unidentified problems can be detected and addressed. Furthermore, testing and other iterative processes enable the derivation of an optimal solution. At this stage, developing a practical AI model tailored to resolving the problem is necessary, with parameters fine-tuned or model improvements implemented while assessing performance during the test stage. Additionally, the program is tested to ascertain its effectiveness in facilitating problem-solving [2], [5], [10], [11]. Table 1 below illustrates the design thinking process in AI education.

TABLE I
PROBLEM SOLVING WITH AI USING THE DESIGN THINKING PROCESS

Design thinking process	AI problem-solving process
Empathize	· Understand data types
Define	· Determine whether AI can be used to solve the problem. · Determine if AI can be utilized to solve the problem efficiently. · Collect and preprocess data. · Visualize data
Ideate	· Statistical data analysis · Design AI models · Design AI problem-solving processes
Prototype	· Develop AI programs. · Test model performance · Model tuning
Test	· Determine if a problem is solvable. · Analyze problem-solving suitability

B. Methods

1) Participants: An AI education program targeting middle school students was implemented to assess the educational efficacy of design thinking in AI education. The study participants comprised first-year middle school students in Korea (13 years). For the research, the subjects were divided into an experimental group and a control group, and the treatment was administered on a group basis. The division into groups was based on class assignment. Individuals were excluded if they failed to participate in all aspects of the treatment or did not engage sincerely with the assessment tools. The study participants had previously received elementary education under the 2015 revised curriculum in Korea, and they were also undergoing education aligned with the same curriculum during this study. Consequently, they were familiar with the block-based programming language environment as they had practiced problem-solving utilizing it. Therefore, within the AI training, an explanation of the programming development environment was not provided; rather, the training concentrated on AI content and design thinking activities.

2) Treatment: To examine the efficacy of design thinking in AI education, treatment employed identical educational content for all groups, with the sole distinction lying in the teaching and learning approach. The control group received AI education through traditional lectures, while the experimental group underwent AI education utilizing design thinking. The specific topic of AI training involved the development of a program for assessing whether an individual is wearing a mask. Considering the students' proficiency level, supervised learning was employed in machine learning to construct a program capable of analyzing images and determining mask presence.

The experimental group participated in seven sessions, whereas the control group engaged in six sessions. Initially, the preparation stage was conducted to initiate the design thinking-based activity. During this stage, the concept of design thinking was introduced in the first session, followed by an explanation of machine learning and supervised learning in the next two sessions to facilitate the subsequent design thinking activity. As the control group did not require a briefing on design thinking, only one session on machine learning and supervised learning was conducted.

The third session involved the empathizing and defining stages. In the empathize stage, a problem scenario was presented wherein wearing masks had become mandatory due to COVID-19. The assigned task was to develop a program for detecting mask presence. The control group received an instructor-led explanation regarding an AI program's importance and underlying principles for mask recognition. Conversely, the experimental group engaged in a human-centered approach, gathering information based on the given problem scenario and undertaking activities to identify the specific data requirements for problem-solving.

In the subsequent defining stage, students were instructed to define the problem of creating an AI program capable of recognizing masks in images. It was assessed whether the defined problem was amenable to AI-based solutions and whether it could be efficiently addressed through AI methods. Data collection, preprocessing, and visualization would have been necessary in normal circumstances. However, due to limitations at the school site, the instructor provided the required data to the learners. In the pilot training program, learners were tasked with capturing their own images and employing that data for program development. Although the accuracy of the model was enhanced through transfer learning in the block-based programming language (Programming development environment: Entry), the accuracy of the AI model was found to be low due to uncontrolled conditions in the students' photographs [24], [25]. Additionally, the process of capturing, collecting, and redistributing photos consumed significant time, prompting the distribution of the same data to all students.

Nevertheless, to impart students with hands-on experience in data collection and preprocessing, the provided data comprised a combination of essential problem-solving data and non-essential data. This allowed students to become familiar with the data collection and preprocessing procedures involved in problem-solving. The fourth session focused on ideate. During the ideate stage, the objective was to explore methods for constructing an AI model to determine whether learners should wear a mask. Teams engaged in brainstorming to generate diverse ideas, which were then evaluated considering the imposed constraints. Subsequently, each team member proceeded to design the program's algorithm and AI model. In the control group, the algorithm and AI model of the program the students intended to create were explained to the teacher. The fifth and sixth sessions were dedicated to the prototype stage. The students translated their algorithm and AI model into practical outputs in this phase. They tested the program's ability to determine whether to wear a mask, made modifications to the algorithm and AI model if necessary, and iteratively enhanced the program. The control group likewise developed a similar program; however, they received guidance from the instructor concerning the algorithm and AI model. The seventh period encompassed the test phase. Students presented their AI models and programs and assessed their performance regarding mask recognition. The instructor provided feedback based on the program's performance. The control group also conducted activities to test its programs.

3) Test tool: This study aimed to assess the educational effectiveness of incorporating the design thinking process with AI by measuring junior high school students' computational thinking (CT) skills. The inclusion of design thinking in the 2022 revised curriculum's information curriculum and its integration into AI education was intended to enhance educational outcomes [15]. Within the 2022 revised curriculum, CT is identified as a fundamental competency in information education, and the curriculum has been designed to foster learners' CT abilities.

CT is the capacity to leverage computing power with the advancement of computing technology effectively, its application in various domains has expanded, thereby elevating the significance of CT as a skill required to employ computing in problem-solving scenarios competently. Consequently, numerous educational programs have been developed to cultivate CT [26], [27]. To effectively address problems using AI, it is imperative to grasp the concepts and characteristics of AI and proficiently utilize them under the given problem context [2], [5]. Consequently, efforts are required to nurture both CT skills and AI literacy within AI education [2], [5], [15], [28], [29], [30]. Therefore, this study employed CT to examine the educational effects of incorporating the design thinking process in AI education.

The Computational Thinking Scale (CTS) developed in [31] and [32] were used to assess the computational thinking skills of Korean middle school students. The CTS was created by analyzing previous studies on existing computational thinking assessment tools, leading to the identification of key factors encompassing abstraction, decomposition, algorithmic thinking, evaluation, and generalization. Initially, 25 preliminary items were formulated based on these factors, and an exploratory factor analysis was conducted, resulting in the final selection of 19 items. The items were designed as self-reported measures, employing a 5-point Likert scale for participant responses. The internal consistency of the items, as indicated by Cronbach's α value, was .91].

As the CTS was originally developed in English, its direct application to Korean students was deemed inappropriate. Consequently, a professional translator was engaged to translate the items into Korean, followed by a back-translation process to ensure item appropriateness. The suitably translated items were then administered to 1369 Korean middle school students, and the obtained data underwent exploratory factor analysis. During this analysis, one item displaying low commonality and factor loadings was eliminated, resulting in a refined set of CTS items tailored to Korean middle school students, accounting for relevant social and cultural contextual factors. The final version of the CTS comprised 18 items, with three items, each representing the factors of abstraction and decomposition, and four items each for algorithmic thinking, evaluation, and generalization. Furthermore, the internal consistency of the scale, as measured by Cronbach's α, was found to be .97 [31], [32].

4) Analysis: In this study, the CT skills of both the control and experimental groups were assessed before and after the treatment. An independent sample t-test was conducted to analyze the CT skills of the two groups in the pre-test, revealing a statistically significant difference. As a result, the post-test CT skills were compared using analysis of covariance (ANCOVA). Furthermore, changes in CT skills within each group, from pre-test to post-test, were examined using paired samples t-tests.

III. Results and Discussion

Upon examining the CT scores of both the experimental groups (M = 3.82, SD = .75) and control groups (M = 3.46, SD = .60) in the pre-test, it was observed that the experimental group exhibited higher CT scores than the control group, with a statistically significant difference between the two groups ($t = 3.28$, $p < .01$). This finding establishes a significant disparity in CT scores between the groups during the pre-test phase. In terms of the specific CT factors, namely abstraction ($t = 2.73$, $p = .01$), decomposition ($t = 2.21$, $p = .03$), algorithm ($t = 3.44$, $p < .01$), evaluation ($t = 3.45$, $p < .01$), and generalization ($t = 2.31$, $p = .02$), notable differences were detected (see Table 2).

TABLE II
CT of Experimental and Control Groups at Pre-Test

Factor	Group	*N*	*M*	*SD*	*t*	*P*
Abstraction	Exp.	86	3.91	.84	2.73	.01*
	Con.	73	3.57	.71		
Decomposition	Exp.	86	3.52	1.04	2.21	.03*
	Con.	73	3.19	.77		
Algorithm	Exp.	86	3.83	.78	3.44	.00*
	Con.	73	3.41	.70		
Evaluation	Exp.	86	4.00	.71	3.45	.00*
	Con.	73	3.59	.78		
Generalization	Exp.	86	3.80	.89	2.31	.02*
	Con.	73	3.50	.73		
Total	Exp.	86	3.82	.75	3.28	.00*
	Con.	73	3.46	.60		

$^{*}p < .05$

Consequently, ANCOVA was employed to compare the CT scores of the experimental and control groups in the post-test. An analysis was conducted to examine the change in CT of the control group that received AI training through the lecture method. Results indicate a notable improvement in CT scores from the pre-test (M = 3.46, SD = .60) to the post-test (M = 3.72, SD = .64) for the control group, with a statistically significant difference observed between the two assessment points (t = -2.35, p = .02). These findings affirm that, despite the instructional format being a lecture method, the inclusion of AI problem-solving experiences and information-based education effectively enhanced the CT abilities of middle school students.

Upon examining the specific CT factors, it was found that all factors exhibited improvement from the pre-test to the post-test. However, a statistically significant difference between the pre-test and post-test scores was only observed in the decomposition (t = -2.90, p =.01) and algorithm (t = -2.40, p = .02) factors. This outcome confirms that factors associated with abstraction significantly influence [28] (see Table 3).

TABLE III
CHANGE IN CT OF THE CONTROL GROUP

Factor	Test	*M*	*SD*	*t*	*p*
Abstraction	Pre	3.56	.71	-1.44	.15
	Post	3.74	.69		
Decomposition	Pre	3.19	.77	-2.90	.01*
	Post	3.56	.82		
Algorithm	Pre	3.41	.70	-2.40	.02*
	Post	3.71	.69		
Evaluation	Pre	3.58	.78	-1.79	.08
	Post	3.84	.76		
Generalization	Pre	3.50	.73	-1.74	.09
	Post	3.73	.75		
Total	Pre	3.46	.60	-2.35	.02*
	Post	3.72	.64		

* $p < .05$

Middle school students who received AI education using design thinking demonstrated improvement in their CT skills on the post-test (M = 3.82, SD = .75) compared to the pre-test (M = 4.16, SD = .84). The observed difference between the pre-test and post-test scores was statistically significant (t = -2.34, p = .02), indicating that the application of design thinking in AI education effectively enhances CT in middle school students. When examining specific factors, the post-test scores showed significant improvement compared to the pre-test in abstraction (t = -3.07, p < .01), decomposition (t = -2.87, p = .01), algorithm (t = -2.24, p = .03), evaluation (t = -2.92, p < .01), and generalization (t = -2.99, p < .01). In contrast, the control group did not exhibit significant differences between the pre-test and post-test scores in these areas. This study provides evidence that AI education incorporating design thinking can have a positive impact on the development of CT in middle school students (see Table 4). Considering the significant difference in CT scores between the experimental and control groups in the pre-test, ANCOVA was employed to analyze the post-test results. The analysis revealed that the experimental group (M = 4.16, SD = .84) exhibited higher CT scores than the control group (M = 3.72, SD = .64) in the post-test, and this difference was statistically significant (F (1, 156) = 11.173, p < .01).

TABLE IV
CHANGE IN CT OF THE CONTROL GROUP

Factor	Test	*M*	*SD*	*t*	*P*
Abstraction	Pre	3.90	.83	-3.07	.00*
	Post	4.18	.87		
Decomposition	Pre	3.51	1.04	-2.87	.01*
	Post	3.99	.02		
Algorithm	Pre	3.82	.78	-2.24	.03*
	Post	4.16	.87		
Evaluation	Pre	4.00	.71	-2.92	.00*
	Post	4.23	.83		
Generalization	Pre	3.80	.89	-2.99	.00*
	Post	4.18	.90		
Total	Pre	3.82	.75	-2.34	.02*
	Post	4.16	.84		

* $p < .05$

Thus, even after adjusting for the initial disparities between the two groups in the pre-test, the experimental group consistently demonstrated significantly higher CT scores than the control group in the post-test.

TABLE V
INITIAL DISPARITIES BETWEEN THE TWO GROUPS

Group	N	Pre-test		Post-test		M	F
		M	SD	M	SD	(Adjusted)	
Exp.	86	3.82	.75	4.16	.84	4.15	11.173*
Con.	73	3.46	.60	3.72	.64	3.73	

* $p < .05$

The middle school students who participated in this study followed the information curriculum based on the 2015 revised curriculum in South Korea, which included AI education. The 2015 revised curriculum aimed to foster CT skills [33]. Previous studies have indicated limitations in the development of CT skills, despite students completing the 2015 curriculum [28], [34], [35]. However, in this study, it was observed that students who underwent AI education in conjunction with their middle school information courses demonstrated effective development of CT skills. It is important to note that although the test instruments, targets, and instructors differed across studies, the positive impact of combining AI education with the middle school information curriculum was consistent. Considering the recent announcement of the 2022 revised curriculum, South Korea has included AI content from the 2015 revised curriculum [15]. Therefore, if the education remains consistent with that employed in this study, it is anticipated that the 2022 revised curriculum will prove effective in promoting CT skills among middle school students.

Furthermore, this study revealed that middle school students who received AI education through design thinking, as opposed to traditional lecture-based instruction, experienced a significant improvement in their CT. These findings suggest that the choice of teaching and learning method in AI education may have an impact on CT development, with design thinking proving to be an effective approach for fostering CT skills in learners within the context of AI education [28],[29]. The results also support the suitability of design thinking as a teaching and learning method in line with the instructional direction outlined in the 2022 revised curriculum for information education [15].

This study specifically adapted and refined the existing design thinking process to align with the problem-solving process of AI. This tailored design thinking process was well-suited for promoting CT development among Korean middle school students [28], [31], [32]. Notably, Nam et al. (2018) conducted a comparative analysis of CT and problem-solving processes in science, mathematics, and engineering. They found that various stages of the problem-solving process in these domains align with different aspects of CT. For instance, "problem recognition" corresponds to "data collection and analysis," "problem definition" aligns with "data representation," "problem decomposition" aligns with "abstraction," "problem solution exploration" matches with "algorithms," and "solution application" corresponds to "automation, simulation, and parallelization." In the context of design thinking, the "define" stage aligns with "problem definition," "ideate" corresponds to "exploring solutions to the problem," "prototype" aligns with "applying solutions," and "test" corresponds to "evaluate and generalize." Thus, the problem-solving process inherent in computational thinking exhibits similarities across different subjects, confirming the efficacy of education using design thinking in fostering CT development [36],[37].

In conclusion, the study's findings suggest that education utilizing design thinking in AI education is more effective in fostering learners' CT skills. Moreover, the incorporation of design thinking into AI education has also been shown to be effective in nurturing CT abilities in learners.

IV. Conclusion

This study aimed to examine the educational efficacy of design thinking in AI education. In pursuit of this objective, a design thinking process tailored for problem solving utilizing AI was established, and an AI education program based on this process was developed. To assess the program's effectiveness, it was implemented with Korean middle school students, focusing on the observation of changes in CT, a fundamental skill in Korean information education.

Results demonstrated that when the AI education program was delivered in a lecture format, Korean middle school students exhibited improvement in CT. However, intriguingly, employing the design thinking process as a teaching-learning approach resulted in greater enhancements in the CT skills of middle school students than the lecture method, even when the instructional content remained consistent. This study conclusively establishes design thinking as an effective method for fostering CT in AI education among middle school students. Additionally, it highlights the effectiveness of an educational approach that integrates the problem-solving process of AI education within the design thinking framework for the development of CT in middle school students.

Previous research has indicated that AI training experiences can have negative effects on learners, leading to the development of unfavorable perceptions and attitudes toward AI. These negative perceptions, in turn, can impede the effectiveness of AI education. However, in the context of this study, it was observed that the application of AI education to middle school students resulted in improved CT skills. This suggests that the difficulties encountered in AI education may be attributed to the existing approach in Korean AI education, which primarily focuses on AI concepts and principles. By addressing these limitations and incorporating design thinking into the educational process, this study demonstrated that design thinking is a suitable method for teaching and learning AI in Korean school settings.

While previous studies have primarily examined perceptions and attitudes toward AI to evaluate the effectiveness of AI education, this study focused on measuring CT as a core competency within information education. The results confirmed a significant educational effect on problem-solving skills; however, changes in learners' competencies in collaborating with AI or utilizing AI in problem situations were not specifically addressed. Therefore, it is recommended that future research investigate AI literacy and changes in learners' competencies by implementing AI education using the design thinking process developed in this study. Additionally, to comprehensively analyze the effectiveness of design thinking in AI education, it is important to explore perceptions and attitudes toward AI through various research approaches.

This study specifically focused on middle school students, as previous research has demonstrated that elementary school students possess distinct perceptions and attitudes toward AI compared to their middle and high school counterparts. Consequently, it is plausible that elementary school students may exhibit different perceptions and attitudes toward AI than middle school students. Thus, it is imperative to extend the application of AI education using design thinking beyond middle school students and encompass elementary and high school students as well.

Furthermore, it is worth noting that in this study, the treatment encompassed seven sessions, including an explanation of the design thinking process. Although these sessions resulted in changes in CT, it is important to acknowledge that prior studies have indicated that changes in CT can occur in the short term but may not be sustained in the long run. Therefore, it becomes necessary to prolong the duration of AI education utilizing design thinking and thoroughly analyze its educational effects over an extended period.

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