International Journal on Advanced Science Engineering Information Technology

Vol.14 (2024) No. 6
ISSN: 2088-5334

Effect of Artificial Intelligence Convergence Education Using ChatGPT on Computational Thinking of High School Students in Korea

Seung-Ju Hong [a], Youngjun Lee [a], Seong-Won Kim [b,*]

[a] *Deparment of Computer Education, Korea National University of Education, 250 Taeseongtabyeon-ro, Cheongju, Republic of Korea*
[b] *Department of Computer Education, Busan National University of Education, 24 Gyodae-ro, Yeonje-gu, Busan, Republic of Korea*
*Corresponding author: *swkim@bnue.ac.kr*

***Abstract*—Artificial intelligence (AI) has been integrated into various fields, accelerating innovation in existing ones. Consequently, AI has been employed in education to drive changes such as learning analytics and personalized learning. Recently, the development of generative AI has further transformed the educational landscape. Given the increasing use of generative AI in education, this study was conducted to explore its educational applications. We developed an educational program incorporating generative AI based on design thinking principles for high school students. To verify its effectiveness, high school students in Korea were selected as research subjects and divided into an experimental group (n=53) and a control group (n=42). A test tool aligned with the 2022 revised curriculum in Korea measured computational thinking skills. The study results showed that the group receiving AI convergence education using generative AI significantly improved their computational thinking. The improvement in computational thinking was also significant compared to the control group, providing strong evidence of the benefits of AI in education. This study confirmed that AI convergence education, utilizing generative AI grounded in design thinking, effectively develops computational thinking skills in high school students. The findings of this research highlight the potential educational value of integrating generative AI into both AI design thinking and convergence education. The study provides reassurance that generative AI can be a powerful tool in enhancing student learning experience and outcomes, paving the way for future educational innovations.**

***Keywords*—ChatGPT; computational thinking; chatbot; artificial intelligence convergence education; sustainable development goals.**

Manuscript received 12 Dec. 2023; revised 14 Jan. 2024; accepted 20 Aug. 2024. Date of publication 31 Dec. 2024.

I. INTRODUCTION

As science and technology, including AI, continue to advance, AI is expanding beyond technology and engineering into various areas such as the humanities, society, and arts. AI is increasingly used to find creative and innovative solutions to previously complex problems. AI technology is increasingly shaping the labor market and economic structure, from everyday life to industry [1],[2].

In November 2020, the government of the Republic of Korea announced its "Education Policy Direction and Key Tasks in the Artificial Intelligence Era" in collaboration with related ministries. The government presented specific plans for AI literacy education and convergence education, emphasizing the importance of AI education in future education. From 2020 to 2025, the plan specified the gradual expansion of AI-related education in schools. Content standards were prepared to link AI to the elementary, middle, and high school curricula. According to sources [3], [4], acquiring knowledge about AI through play and experience during elementary school is recommended, focusing on understanding AI principles and their real-life applications during middle school and integrating AI principles with other subjects during high school.

In July 2021, the Ministry of Education of the Republic of Korea announced the "Results of inspection of educational policy direction and core task progress in the artificial intelligence era." One of the essential tasks was preparing content standards for AI education in elementary, middle, and high schools and completing the development and distribution of auxiliary teaching materials. Policies to strengthen AI convergence education capabilities for in-service teachers are currently being pursued, with plans to expand such education in the future [4], [5].

The Ministry of Education has stated that the talent required in the era of the 4th Industrial Revolution must

possess complementary and convergent capabilities rather than fragmented knowledge and abilities [3], [5]. Specifically, the students should acquire creativity and communication, collaboration, and problem-solving skills through critical thinking. The significance of creativity, thinking, information collection and processing, and problem-solving is emphasized due to the development of cutting-edge information and communication technologies, including AI [3].

To explore and promote a society driven by AI, it is crucial to acknowledge its impact and comprehend its concepts and principles. The ability to creatively solve real-life problems using AI is essential. Therefore, we need AI convergence education to solve complex problems by integrating AI into various industrial fields and other contexts [3].

ChatGPT was launched on November 30, 2022, and within the first week of its release, it secured over 1 million subscribers. It is currently one of the most impressive platforms, with a user-friendly interface and many users gained over in a short period [6]. ChatGPT provides services with sophisticated language capabilities that can perform complex tasks [6], [8]. However, the potential impact of AI chatbots, including ChatGPT, on education remains uncertain [6]–[9], [11].

ChatGPT and other generative AI apps are already impacting education and causing paradigm shifts in existing practices. In 2022, researchers launched the service and began studying its potential impact on teachers, students, and policy. Researchers have started to investigate the effectiveness of ChatGPT in educational activities, including research, teaching, and assessment. They have found that automating tasks and processes allows for more time to interact with students [7], [9]–[11]. Stokel-Walker (2023) has described ChatGPT as a "game changer, " potentially replacing traditional assignments and assessments, such as essay writing. The impact of ChatGPT may be more significant than anticipated, as demonstrated by the emergence of AI chatbot services like ChatGPT [9]. Zhai [10] analyzed the implications of AI on education, including the use of AI tools such as ChatGPT in learners' educational activities. According to the authors, the emphasis should be on enhancing students' creativity and critical thinking abilities rather than relying solely on AI technology. They also suggested new evaluation methods prioritizing creativity and critical thinking, which AI cannot replicate.

Baidoo-Anu and Ansah [8] conducted an exploratory study to analyze the potential benefits of ChatGPT in advancing education and learning. The study focused on the benefits of ChatGPT, including personalized interactive learning, continuous feedback on teaching and learning, and its potential as a learning tool. This method could be used with other educational methods that stress human interaction and understanding. It could serve as a learning tool for personalized tutoring, automated essay grading, language translation, interactive learning, and adaptive learning. The limitations of ChatGPT were analyzed, including the lack of human interaction, limited understanding, bias in learning data, lack of creativity, dependence on data, lack of context understanding, limitations in personalized education functions, and privacy protection [9], [11].

Rahman and Watanobe [11] investigated the potential opportunities and concerns of ChatGPT in education from the viewpoints of teachers and students. They explored using AI chatbot services in education, such as creating lesson plans and responding to parent emails. They found that it can reduce time and cost if used in various ways, such as creating a student evaluation rubric, grading student essays, and writing student letters of recommendation. However, they also noted that more is needed in many areas, such as educational creativity and student relationships. Nevertheless, it has been confirmed that it is now used for instructor class preparation.

However, education authorities in New York City and Western Australia have expressed concerns regarding AI technology's potential negative impact on learning and its content's safety and accuracy. Additionally, it has been criticized for hindering the acquisition of critical thinking and problem-solving skills and making it difficult to identify students' strengths and weaknesses in educational evaluations. As a result of these concerns, some education authorities have blocked access to AI chatbot services [12], [13].

Previous research has identified generative AI's potential advantages and limitations through ChatGPT. An educational use plan was proposed to promote personalized interactive learning. ChatGPT combines natural language processing and AI to create and respond to natural conversations like talking to someone. Students and AI chatbots interact one-on-one through conversation. The potential of ChatGPT as an educational tool was explored and confirmed. However, it does not guarantee perfect human-level conversation, and there are concerns that errors or inappropriate responses may occur [8], [9].

As interest in AI convergence education increases, there will be a growing demand for chatbot services that combine AI with cross-curricular topics. In this study, we investigated the use of ChatGPT in actual school settings to assess its potential for AI convergence education. However, further research will be needed to confirm its effectiveness in promoting significant learning outcomes. This study aimed to determine the impact of AI chatbot services by developing and implementing an AI convergence education program for high school students. The goal was to confirm meaningful learning effects by applying ChatGPT to AI convergence education in actual school settings. Thus, this study's objective was to create an AI convergence education program for high school students using an AI chatbot.

II. Materials and Method

A. Related Works

1) Converging AI Education: Many countries worldwide discuss the content and methods of AI convergence education for K–12 students [14]. The programs developed in this study aim to equip students with digital literacy skills that can leverage AI and big data. To develop the ability to understand and use AI to solve real-life problems, it is essential to provide education on AI and its convergence [15].

In the United States, the Computer Science Teachers Association (CSTA) standards for 11th and 12th-grade algorithms and programming include topics related to AI education. Additionally, the AI education guideline "Artificial Intelligence for K12 Students (AI4K12)" has provided an educational framework [16], [17]. Science,

Technology, Engineering, and Mathematics (STEM) education leads to the development of teaching and learning materials and curricula that integrate computer science and AI with other subjects in elementary, middle, and high schools [18].

In 2017, the Chinese government proposed the content of AI education in elementary and middle schools through the "Next Generation Artificial Intelligence Development Plan" of the State Council of China. Since then, the government has been promoting the "Educational Informatization 2.0" policy and building an educational environment to teach AI [19]. Similarly, the United Kingdom proposed including the basic knowledge and understanding necessary to explore the world centered on AI in the curriculum for elementary school students through the 2019 "AI in the UK" report [20].

The Ministry of Education (2021) defined AI convergence education as combining AI with two or more academic or industrial fields to solve a problem [21]. In the educational application of AI, various terms and definitions are often mixed, such as AI understanding education, AI utilization education, and AI convergence education [22],[23].

In 2020, the Ministry of Education announced plans for science, mathematics, information, and convergence education related to AI. The stated aim of education was to cultivate the basic knowledge necessary for the future information society [24]. A comprehensive education plan was established by converging AI and education, emphasizing the connection between subjects—the plan aimed to develop future-oriented and effective policies through a systematic approach.

In the 2022 revised curriculum overview announced by the Korean Ministry of Education in November 2021, the Ministry emphasized the importance of cultivating digital literacy among elementary and middle school students. The plan proposed cultivating AI capabilities in all students based on digital literacy and supporting AI education for the future era [25]. Thus, AI is now used in combination with various disciplines and technologies. It was also suggested that the 2022 revised curriculum integrate digital and AI content elements at the appropriate achievement level [26].

Previous research targeting elementary and middle school students on AI convergence education has shown various recent trends. The analysis of prior research suggests that many research methods have been developed for programming programs using AI models in AI convergence education. As a result, programs utilizing an AI model have been created [28]. In the field of AI convergence education, the primary objective is to develop programs that utilize AI models to solve cross-curricular problems [14], [20], [27]–[29]. Therefore, we aimed to create an educational program that employs AI chatbots to select and solve cross-curricular convergence topics that can effectively address real-life issues.

2) AI Chatbot Service: ChatGPT is a chatbot service developed by OpenAI based on the GPT generative pre-trained transformer. It was launched in November 2022 and can generate text while maintaining a human-like conversational style [30]. ChatGPT is a program that utilizes AI technology to create conversations automatically. It can provide natural conversations by learning from a large amount of conversation data. The technology combines natural language processing and AI, allowing for natural conversations that simulate human interaction [6], [9].

Unlike other existing chatbots, this chatbot understands the intention and context of the conversation and provides an accurate response. It can even correct an incorrect answer by asking follow-up questions.

Previous studies have shown that AI chatbot services can provide customized recommended questions or guidance for individualized education. This approach effectively finds learning materials or activities that fit students' needs and interests through recommended questions. It has been confirmed that this method can improve student participation and motivation and increase student satisfaction [8], [11]. However, there are concerns about algorithmic bias and the potential for these systems to reinforce existing prejudices or perpetuate stereotypes [8], [10], [11].

This study used AI chatbots to provide personalized learning based on each student's learning level, interests, and tendencies. With this approach, students can obtain detailed explanations of background knowledge through AI during class. Instead of a uniform learning path created by the teacher being applied to all students, each student can follow their learning path to achieve their level of success. Additionally, students can utilize an AI chatbot to ask questions at any time, and immediate responses can inspire students' interest in learning and facilitate a smooth learning process.

Moreover, students can enhance their ability to comprehend and utilize AI for problem-solving. Generative AI programs facilitate interactive learning by adapting to the student's speaking, tone, and writing style to generate the desired response, simulating a conversation. This enables students to improve their communication skills by expressing their thoughts more effectively.

This approach also allows the presentation of creative ideas and problem-solving methods by linking generative AI programs with various subjects. By developing a lesson plan based on this approach, teachers can provide a range of learning activities that can help students develop their creative problem-solving skills. Examples of such activities include essay topics, projects, and discussion classes, which can be tailored to the needs of the teacher or student.

AI chatbots can help break away from stereotypes and find solutions through natural conversations with learners. They can ask questions about the surrounding environment and objects, determine the issue's current status, suggest various attempts or experiences, actively respond to problems, and find appropriate methods. Problem situations can be analyzed objectively from different perspectives, including those of experts and fellow learners. Advice and guidance on learning can also be provided. This study explored using an AI chatbot as a personalized learning tool. The chatbot stimulates problem-solving skills through conversation and acts as an assistant to elicit desired responses from students.

3) Computational Thinking (CT): The study focused on developing CT, which involves understanding complex problems and implementing creative solutions using computer science concepts and computing systems. If CT is developed through software education, it can improve overall problem-solving ability by utilizing the computer's

computational ability as if it were the learner's natural ability to solve various problems encountered in daily life [31]–[33].

Subjects such as mathematics and science are also practical in developing problem-solving skills. However, software engineering education is significant because it supports the development of cognitive capabilities at a different level. In other words, it can be expected to have a metacognitive education effect, where new cognitive abilities based on computing are added to existing human cognitive skills [34]–[36].

Design thinking is a process that effectively solves problems using computing. Thus, developing CT skills improves analytical problem-solving, logical thinking, and expansive problem-solving across all subjects and encourages a proactive attitude [35], [36]. Learners use CT to solve problems efficiently and create questions to find new and effective solutions [37],[38]. Problem-solving competency has been identified as an ordinary skill among subjects in the AI convergence education program that utilized chatbots [29]. The program confirmed that the subjects could solve problems using AI.

B. Materials

This study investigated the achievement standards of AI problem-solving elements for each subject of the 2022 revised curriculum and selected related subjects using an AI chatbot as part of an education program on AI convergence. The program was designed based on the Korean Ministry of Education's guidelines for AI convergence education. The curriculum design aims to integrate the "Sustainable Development Goals" (SDGs) and "Use of Artificial Intelligence" into the subjects. Table 1 shows the achievement standards and content elements of convergence science exploration, creative engineering design, and AI subjects.

TABLE I
SUBJECTS FOR AI CONVERGENCE IN KOREA'S 2022 REVISED CURRICULUM

Subject	Area	Achievement Criteria
Convergence Science Exploration	Understanding convergence science exploration and the prospects for convergence science exploration	You can investigate cases of the use of digital inquiry tools and technologies, including AI, and evaluate the significance of using them in scientific inquiry. You can discuss ways to solve humanity's complex problems using the convergence of science and technology.
Creative Engineering Design	Creative engineering design project	Through creative engineering design projects, students explore and solve convergent engineering problem situations, understanding the convergent characteristics of creative engineering design and developing creativity, confidence, and positive attitudes and values toward engineering.
AI Basics	AI project	Explore ways to apply AI to meet the SDGs and derive topics suitable for AI project activities. Develop a project implementation plan based on the AI problem-solving process.

The educational content of AI convergence education aims to solve problems related to the subject learning content elements of each subject under the SDGs. The SDGs were adopted at the United Nations General Assembly on September 25, 2015, presenting 17 goals that address significant development challenges for humanity. The overall goal is to ensure a sustainable, peaceful, prosperous, and equal life for all people. These individual goals encompass global challenges critical for human survival [39],[40]. The topic was selected from the SDG topics in the student's field of interest. The course involved a problem-solving project class where learners explored selected SDG topics using an AI chatbot.

The AI convergence education program is designed to address real-life problems related to the themes of SDGs and provide solutions using AI. Its purpose is to prepare high school students for the future challenges of an AI convergence society. Previous research designed an AI convergence education program using the human-centered creative problem-solving method of design thinking [41]–[44]. The program plans to utilize AI chatbot services during learners' problem-solving process actively.

AI chatbots are recognized as personalized learning tools tailored to learners, guiding them to share knowledge and learn through cooperation. Learners participate in conversations with the chatbot, generating questions and receiving responses that understand intent and context. They are encouraged to continue generating questions to check the current status of the problem. During the conversation between the learner and the AI chatbot, incorrect answers are corrected, and the learner is encouraged to explore by creating and combining ideas. Feedback is provided at each stage, and learning activities are analyzed from various perspectives by organizing them by stage. The learner guides the conversation to arrive at the desired answer through interaction with the AI chatbot. In addition, learners are encouraged to seek creative solutions that go beyond stereotypes and present better alternatives.

This program aims to offer personalized learning by assisting learners in developing problem-solving skills through an AI chatbot service. The learning content includes problem-solving activities that follow the design thinking process, including "empathy," "problem definition," "idea creation," "prototype," and "test." Each step involves using an AI chatbot to facilitate the learning process. The class was structured as follows: the Experimental group (Exp.) and Control group (Con.) received overall guidance, an introduction to learning tools, problem definition, idea creation, prototype development, and testing. The language used throughout the text is clear, objective, and value-neutral, with a formal register and precise word choice. The text follows conventional structure and formatting, including consistent citation and footnote style. The content has not been altered beyond necessary improvements for objectivity, comprehensibility, and grammatical correctness. Exp. utilized an AI chatbot for problem-solving, while Con. relied on search engines and literature information services. Classes were held for three weeks, with a total of one to six classes per week, each lasting two hours.

Learners utilized information devices, including computers, tablet PCs, and smartphones. Continuous feedback and revision were essential to problem-solving activities and were conducted about previous learning and class activities. The problem-solving activities of the

education program for AI convergence were conducted through classes organized according to the framework shown in Table 2. The learning content was reviewed and consulted by 14 individuals, including 11 teachers and three experts. The difficulty level was adjusted to accommodate high school students' understanding, achievement level, and problem-solving ability.

During the first session, we provided guidance on using AI chatbots (ChatGPT), search engines, and literature information services such as Google Scholar and RISS (Korea Academic Information Service). We also provided information on the methods used in the AI convergence education program for both Exp. and Con. The information processing service was carried out using different tools. The chatbot utilizes AI to engage in problem-solving conversations, while the search engine and literature information service solve problems by searching for information based on keywords.

TABLE II
AI CONVERGENCE EDUCATION PROGRAM BY GROUP

Class	Exp.	Con.
1	Introduction to the entire class about how to use the AI chatbot service	Introduction to overall class guidance and how to use search engines and literature information services
2	Empathy activities: Creating a persona, conducting an interview (discomfort, concerns, points for improvement, etc.), analyzing the characteristics of the target	Empathy activities: Creating a persona, conducting an interview (discomfort, concerns, points for improvement, etc.), analyzing the characteristics of the target
3	Defining the problem: Storytelling, selecting SDG topics, analyzing the problem (5W1H)	Defining the problem: Storytelling, selecting SDG topics, analyzing the problem (5W1H)
4	Idea generation: Brainstorming, mind map, SCAMPER, WHAT IF?, forced connection method, PMI, Evaluation matrix method	Idea generation: Brainstorming, mind map, SCAMPER, WHAT IF?, forced connection method, PMI, Evaluation matrix method
5	Prototype: Writing a design proposal, writing an idea proposal, 3D modeling	Prototype: Writing a design proposal, writing an idea proposal, 3D modeling
6	Test: Get feedback, revise, present	Test: Get feedback, revise, present

During the second stage, known as the "empathy" stage, the focus is on selecting the target and defining the problem related to the topic. This involves analyzing the target's characteristics and situation and conducting an interview while assuming a persona. The interview helps to identify inconveniences, concerns, and areas for improvement. The goal is to gain insight into meaningful tasks by understanding the subject's characteristics and environment.

During the "defining the problem" activity in the third session, learners define the problem they aim to solve by analyzing SDG topics and targets. This is based on the results of the empathy activity in the second session, which provides insight into the target audience's needs. The defined problem is then analyzed using an AI chatbot to identify specific details. It is important to explicitly express the problem being addressed and to conduct activities to elucidate and analyze the issue from multiple perspectives.

During the fourth session's "idea generation" stage, fundamental design alternatives are generated using an AI chatbot. The aim is to expand ideas and find solutions through the learner's input and the chatbot's inquiries. The learning activities provide techniques for divergent thinking (brainstorming, mind mapping, SCAMPER, WHAT IF?, forced connection method) and convergent thinking (PMI, Evaluation matrix method) to be used separately or integrated into the problem-solving process. Students are guided to use these techniques.

During the "prototype" stage in the fifth session, the learner writes a design and idea proposal based on the results of the third and fourth session activities. The proposal aims to produce results using an AI chatbot. The proposed solution's characteristics are presented and visualized through 3D modeling to enhance comprehension and elicit deeper empathy.

During the sixth "test" stage, the learner's problem-solving reports are organized in a portfolio format to showcase the process. The portfolio includes a design proposal, idea proposal, and 3D modeling, all completed with teacher and student feedback. Opinions on improvements are taken into account before finalizing the product.

Through design and idea proposals, as well as 3D modeling, we created learning outcomes that can realistically implement ideas. We utilized divergent and convergent thinking techniques to play a central role in problem-solving, allowing learners to explore information, check the execution process, and find various solutions through strong problem-solving skills.

C. Methods

1) Research Overview: This study examined the effectiveness of AI convergence education with high school students using an AI chatbot service. The treatment was performed for each group. The study involved 95 students from a general high school in Korea, divided into two groups: an Exp. consisting of 53 people and a Con. composed of 42 people. To assess the effectiveness of the education, a test was administered before and after the treatment. The pre-and post-test results were later analyzed, and a conclusion was drawn.

2) Questionnaire: This study aimed to analyze the impact of AI convergence education on CT through an AI chatbot service. CT is considered a fundamental skill in digital literacy and is taught through various tools, such as search engines and literature information services [4]. Previous research has identified CT as a necessary competency for problem-solving in AI convergence education [5]. Therefore, it is suitable for measuring the effectiveness of AI convergence education using chatbot services [36],[37]. Thus, this study utilized CT to analyze the effectiveness of AI convergence education.

The study applied a test tool to measure the CT of Korean high school students. The tool was based on items from Tsai, Liang, and Hsu [45] on the Computational Thinking Scale (CTS) and consisted of 18 questions in total (three abstraction questions, three decomposition questions, four algorithmic

thinking questions, four evaluation questions, and four generalization questions). The Cronbach's alpha value was .97 [45], [46].

Tsai et al. [45] validated the CTS based on Selby and Woodland's framework to evaluate the thinking process of CT among Taiwanese middle school students. The CTS consists of 19 questions measuring the thinking process for general and specific problem-solving situations in five dimensions of CT: abstraction, decomposition, algorithmic thinking, evaluation, and generalization. The questions were rated on a 5-point Likert scale, and Cronbach's alpha value was .91.

Hong and Kim [46] utilized a CT test tool to verify the effectiveness of an AI education program. To ensure validity for Korean middle school students, they removed the item "I usually think of a problem from a whole point of view, rather than looking at the details," which had low commonality and low factor loading, according to expert review and exploratory factor analysis. Table 3 displays the test tool used in this study.

TABLE III
CONSISTS OF CTS

Factor	*N*	Cronbach's α	Total
Abstraction	3	.86	
Decomposition	3	.85	
Algorithmic thinking	4	.88	.97
Evaluation	4	.90	
Generalization	4	.86	

3) Treatments: This study was conducted at a single general high school. During course load optimization, Exp. and Con. had two classes selected to participate in an AI convergence education program. Exp. received an AI convergence education program that utilized an AI chatbot. Con. used a search engine and literature information service. After the program, the data were analyzed. Exp. and Con. underwent an AI convergence education program using information devices such as tablet PCs and smartphones. The program consisted of six sessions conducted over two weeks by the same teacher.

4) Analysis: The effectiveness of the AI convergence education program using the AI chatbot service was analyzed using independent sample t-tests and paired sample t-tests. The independent t-test was used to verify the equality of Exp. and Con. in pre-and post-tests. The paired sample t-test was used to analyze the change in CT from pre- to post-test in Exp. and Con.

III. RESULT AND DISCUSSION

A. Computational Thinking of the Two Groups in the Pre-test

In the pre-test, Con. ($M = 3.68$, $SD = .71$) scored higher than Exp. ($M = 3.63$, $SD = .76$). However, there was no statistically significant difference in the CT of the two groups ($t = .36$, $p = .72$). The specific factors analyzed were abstraction ($t = -.49$, $p = .63$), decomposition ($t = 1.01$, $p = 0.31$), algorithmic thinking ($t = .37$, $p = .71$), evaluation ($t = .70$, $p = .49$), and generalization ($t = -.06$, $p = .96$). The pre-test confirmed that Con. and Exp. were identical. Table 4 shows the CT of both groups in the pre-test.

TABLE IV
COMPUTATIONAL THINKING OF EXP. AND CON. IN THE PRE-TEST

Factor	Group	*N*	*M*	*SD*	*t*	*p*
Abstraction	Con.	42	3.69	.78	–.49	.63
	Exp.	53	3.76	.78		
Decomposition	Con.	42	3.63	.90	1.01	.31
	Exp.	53	3.45	.84		
Algorithmic thinking	Con.	42	3.60	.80	.37	.71
	Exp.	53	3.53	.83		
Evaluation	Con.	42	3.90	.73	.70	.49
	Exp.	53	3.78	.85		
Generalization	Con.	42	3.59	.82	–.06	.96
	Exp.	53	3.60	.86		
Total	Con.	42	3.68	.71	.36	.72
	Exp.	53	3.63	.76		

B. Changes in computational thinking in control groups

The post-test ($M = 3.85$, $SD = .91$) showed an improvement in CT compared with the pre-test ($M = 3.68$, $SD = .71$) for Con. However, the statistical analysis did not reveal a significant difference between the two tests ($t = 1.00$, $p = .32$). Therefore, no significant changes were observed in the CT or detailed factors of Con. Table 5 showed that the change in CT of Con.

There were no significant differences found in abstraction ($t = -1.56$, $p = .13$), decomposition ($t = -.72$, $p = .48$), algorithmic thinking ($t = -1.37$, $p = .18$), evaluation ($t = .30$, $p = .77$), and generalization ($t = -1.37$, $p = .18$).

TABLE V
RESULTS OF CHANGE IN COMPUTATIONAL THINKING IN CON.

Factor	Test	*M*	*SD*	*t*	*p*
Abstraction	Pre	3.68	.79	–1.56	.13
	Post	3.97	.90		
Decomposition	Pre	3.63	.90	–.72	.48
	Post	3.76	.94		
Algorithmic thinking	Pre	3.60	.80	–1.37	.18
	Post	3.85	.95		
Evaluation	Pre	3.90	.73	.30	.77
	Post	3.85	.93		
Generalization	Pre	3.59	.82	–1.37	.18
	Post	3.85	.98		
Total	Pre	3.68	.71	–1.00	.32
	Post	3.85	.91		

C. Changes in Computational Thinking in Experimental Groups

The post-test means ($M = 4.28$, $SD = .67$) of Exp. were found to be significantly improved compared with those of the pre-test ($M = 3.68$, $SD = .71$), $t = -4.38$, $p < .01$. The factors contributing to this improvement were abstraction ($t = -3.58$, $p < .01$), decomposition ($t = -4.76$, $p < .01$), algorithmic thinking ($t = -4.22$, $p < .01$), evaluation ($t = -3.73$, $p < .01$), and generalization ($t = -4.01$, $p < .01$). The post-test values for all detailed factors showed improvement compared to those of the pre-test.

These results confirm that the AI convergence education program, which utilizes AI chatbots, improved the computing thinking ability of high school students. The program was found to be effective in improving the thinking process of CT. Table 6 shows that the CT of Exp.

TABLE VI
RESULTS OF CHANGE IN COMPUTATIONAL THINKING IN EXP.

Factor	Test	*M*	*SD*	*t*	*p*
Abstraction	Pre	3.76	.79	–.3.58	.00**
	Post	4.31	.67		
Decomposition	Pre	3.45	.84	–4.76	.00**
	Post	4.21	.80		
Algorithmic Thinking	Pre	3.53	.83	–4.22	.00***
	Post	4.24	.77		
Evaluation	Pre	3.78	.85	–3.73	.00***
	Post	4.35	.57		
Generalization	Pre	3.60	.86	–4.01	.00***
	Post	4.26	.69		
Total	Pre	3.63	.76	–4.38	.00***
	Post	4.28	.67		

**$p < .01$, ***$p < .001$.

D. Post-Test

The post-test revealed a significant difference in CT between Con. ($M = 4.28$, $SD = .67$) and Exp. ($M = 3.85$, $SD = .91$), $t = –2.63$, $p = 0.01$. Detailed analysis showed statistically significant differences in abstraction (t = –2.14, p = .04), decomposition (t = –2.49, p = .01), algorithmic thinking (t = –2.25, p = .03), evaluation (t = –3.25, p = .01), and generalization (t = –2.45, p = .02). Table 7 showed that CT of Con. and Exp. in the post-test.

TABLE VII
COMPUTATIONAL THINKING OF EXP. AND CON. IN THE POST-TEST

Factor	Group	*M*	*SD*	*t*	*p*
Abstraction	Con.	3.97	.90	–2.14	.04*
	Exp.	4.31	.67		
Decomposition	Con.	3.76	.94	–2.42	.02*
	Exp.	4.21	.80		
Algorithmic thinking	Con.	3.85	.95	–2.25	.03*
	Exp.	4.24	.77		
Evaluation	Con.	3.85	.93	–3.25	.01**
	Exp.	4.35	.57		
Generalization	Con.	3.85	.98	–2.45	.02*
	Exp.	4.26	.69		
Total	Con.	3.85	.91	–2.63	.01*
	Exp.	4.28	.67		

*$p < .05$, **$p < .01$.

Significant differences in CT and detailed factors were observed between the two groups. Thus, the study confirmed that the AI convergence education program, which utilizes an AI chatbot, positively impacts the CT of high school students. The program is effective in improving specific factors such as abstraction, decomposition, algorithmic thinking, evaluation, and generalization. A corresponding sample t-test was conducted to verify whether there was a significant difference in the post-test results between Exp. and Con. The study revealed a significant difference between Exp. and Con. ($t = 4.347$, $p < .001$) based on the mean comparison.

The study confirmed that AI chatbot services in AI convergence education improve learners' CT, specifically in abstraction, decomposition, algorithmic thinking, evaluation, and generalization through problem-solving activities. It also confirmed that the convergence of AI, including problem-solving processes, can enhance computing thinking abilities. However, further studies are needed to investigate whether there is a learning effect in AI convergence education across various other subjects.

IV. CONCLUSION

This study examined the impact of AI chatbots for problem-solving activities in AI convergence education on high school students' CT. It designed, implemented, and evaluated a problem-solving learning program using an AI chatbot service based on the principles of the design thinking process. The study conducted pre- and post-tests using a test tool to measure CT.

The program was developed and implemented for this purpose, and the results have been presented here. The study found that the AI convergence education program, mainly when using AI chatbots, significantly improved the CT of high school students. In particular, students who participated in an AI convergence education program using an AI chatbot service showed significant improvement compared with Con. This improvement was confirmed across various elements of CT, including abstraction, decomposition, algorithmic thinking, evaluation, and generalization.

AI chatbots have been shown to significantly improve high school students' CT, supporting their use in AI convergence education for problem-solving learning. Additionally, the study found that AI chatbots significantly impacted high school students' problem-solving skills, which supports previous research indicating that chatbots have a positive effect on students' performance as personalized learning aids. The AI convergence education program utilizes an AI chatbot to facilitate individual problem-solving activities for students. In other words, these results confirm that the AI chatbot functioned as a personalized learning aid for students. Using an AI chatbot as a customized learning aid can positively impact problem-solving in AI convergence education. Learners can utilize this tool for customized learning.

In this study, we utilized an AI chatbot as a personalized tutor to provide individualized education tailored to each student's academic level. Our findings confirmed that the learning goals were achieved, and the students' CT improved, as evidenced by the final evaluation results. This study's AI convergence education course allowed personalized learning based on each student's learning level, interest, and inclination. Additionally, learners who used the AI chatbot service for problem-solving and those who used the normal search engines had more effective outcomes.

The study implemented a learner-centered approach, encouraging students to recognize the AI chatbot service as a collaborative learning partner. This promoted knowledge sharing and acquisition through collaboration between AI chatbots and learners. Interactive project collaboration, where learners explored topics of their choice and solved problems using AI chatbot services, positively affected learning CT and problem-solving.

The education of AI convergence, which utilizes chatbots powered by AI, is based on the achievement standards of convergence science exploration, creative engineering design, and the fundamentals of AI. This education covers subjects related to problem-solving using AI, as outlined in the 2022 revised curriculum. The tool was developed to analyze CT, an essential competency in information-based subjects. However, it is limited to only studying this specific ability. Further research is needed to diagnose and cultivate common core competencies of science and liberal arts subjects. Additionally, research should be conducted to analyze changes in

convergence knowledge and evaluate convergence education's effectiveness.

This study focused on high school students, indicating a need for future research on middle school students. Additionally, AI-based education programs should be developed and analyzed. It is important to note that the results of this study cannot be generalized to middle school students, and further research is necessary to investigate the impact of AI convergence education programs on the CT of this age group.

The study focused on the specific cognitive abilities affected by AI convergence education. While the primary focus was on CT, exploring potential changes in other competencies related to AI convergence education would have been valuable. Given the dynamic nature of educational environments, it is vital to analyze the multifaceted effects of AI chatbots on various aspects of learning, such as critical thinking, creativity, and collaboration skills. Future research should investigate the intricate interactions between AI chatbots and various educational competencies. Furthermore, analysis is required to determine the overall impact of AI integration in fostering learners' future capabilities. Therefore, to generalize the research, research should be conducted to implement AI convergence education in various subjects and analyze its effects.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant, which was funded by the Korea government (MSIT) (No. 2022R1G1A1004701).

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