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A Study on Computational Thinking for Major of Computer Science

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***Abstract*—Recent advances in artificial intelligence and Software have resulted in a paradigm shift in education, necessitating greater changes in educational methods and environments. Many countries worldwide have highlighted computational thinking as the core competence related to software education, leading to an increase in the number of studies focusing on computational thinking in Korea as well. Future demands must be analyzed, and curricula must be improved through in-depth education in computational thinking. Therefore, computational thinking curricula currently offered by universities for students majoring and not majoring in related fields must be reformed for precise educational goals. While research on computational thinking for non-major students has been consistently conducted, curricula for major students are inadequate, and there is a lack of learning opportunities because of the expectation that education on computational thinking for computer science major students will be naturally achieved. Thus, for the purpose of improving the computational thinking education for computer science major students, this study conducted a survey consisting of six questions on "perception of computational thinking" and 11 questions on "need of computational thinking" among 313 students majoring in computer science at a university in Korea. In the study results, 177 students (56.5%) answered "I do not know" for the question "I know what computational thinking is well enough," indicating that computational thinking education must be expanded and considered not only for non-computer science majors but also for computer science major students.**

***Keywords*— Computational thinking; computer education; software education; artificial intelligence; curriculum.**

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I. INTRODUCTION

Recent advances in Artificial Intelligence (AI) and Software (SW) have resulted in a paradigm shift in education, necessitating greater changes in educational methods and environments. Many countries worldwide have announced their education policy direction and core tasks aimed at changes in education in the "digital era" and are currently focusing on AI and SW competence for ensuring digital literacy at all levels of society [1]. Korea's new course of study advocates "education for a better future for all" [2]. The main content focuses on the goal of cultivating students' basic knowledge and competence, as well as expanding information education in all grades of school in the digital transformation era [3]. In particular, computational thinking (CT) is the most important competence that must be developed in relation to SW education. Other countries have already recognized the importance of CT in SW education and revised their information education curricula to improve students' CT skills. Korea has also sought to cultivate students' problem-solving skills based on CT [4],[5].

The core competencies suggested in the 2015 revision of the information education curriculum include information culture knowledge, cooperative problem-solving skills, and CT. Continuous research has been conducted on CT in which a given command is creatively and logically processed to solve problems, and the need to focus on solving problems has been suggested rather than simply providing education or imparting knowledge [6], [7].

In the 2018 International Computer and Information Literacy Study (ICILS), the seventh graders' computer and information literacy and CT were evaluated. The major results showed that Korean students have the second-highest computer and information literacy achievement among the 12 participating countries, which is outstanding. Furthermore, students who learned computer and information literacy as well as CT performed well on a CT test [8].

It is difficult to impart sound CT knowledge, technique, propensity, and strategy through field practice such as programming in training for computer and network application programs; cultivating basic theoretical knowledge of CT in the basic course of computer study has a significant impact on improving students' core abilities and learning methods [9], [10].

Therefore, training CT skills should begin in elementary school and continue through high school until entering college or university. In addition, the education on CT received in elementary to high school must be deepened in universities to analyze future demands of CT, and the curricula for computer science and non-computer science majors should be reformed to ensure students understand the meaning of CT and receive reasonable education encompassing a creative mindset [11], [12].

The revision of information education curricula in Korea from elementary to high school is expected to be linked with AI- and SW-related universities; however, there is a lack of research on CT and systematic learning directions for computer science majors when compared with research on CT for non-computer science majors [13]. Students majoring in computer science typically have inadequate training or education in CT and insufficient opportunities to receive in-depth learning, owing to the expectation that their CT skills will be naturally developed through their course of study. In fact, the survey of computer science majors demonstrated unexpected results. Because there is a clear difference in the knowledge of information education between computer science and non-computer science majors, the CT education curriculum of computer science majors must be revised to develop SW education [14],[15]. Therefore, this study aims to analyze the CT education curricula in Korea for fostering future talents in the digital era and further analyze the perception of CT, which is the core competence of computer science majors, to propose a future direction for CT education.

II. Materials and Method

A. Background

1) Computational Thinking: CT refers to the ability to simplify complex problems and then logically and efficiently solve them, as computers do. Computational thinking is the most essential competence in the digital era [13]. Digital talents referred to in the "Comprehensive Plan for Nurturing Digital Talents" announced by the Ministry of Education are individuals equipped with the knowledge and competence required for developing, utilizing, and operating new digital technology [14]. As the demand for digital talents is rising sharply across various fields and in society as a whole, the comprehensive plan aims to nurture novice (high school graduate, associate's degree), intermediate (bachelor's degree), and advanced (master's, doctorate degree) level of talents from 2022–2026. A massive digital transformation has been demanded in the education field from elementary to high schools to lifelong learning, owing to the growth of the digital industry. Furthermore, the "1 Million Digital Talent Cultivation" policy has been promoted to close the digital competence gap and lack of talent in new technology and industry fields [15], [16].

For implementing such a policy, CT education for computer science majors should be differentiated from CT education for non-computer science majors. Digital convergence education for computer science majors that incorporates AI + X should be improved to ensure that students can experience various digital educational content, and basic knowledge of computer science majors should be enhanced through CT education [17]. Therefore, it is crucial to foster digital talents having basic CT competence, which is the fundamental element of SW education, based on periodic background. This study, therefore, proposes a learning method for heightening CT competence and emphasizes the importance of CT in SW education of the future digital era by effectively analyzing the perception of CT among computer science majors and the effect of their perception of CT.

2) Definition of CT in Korea: As listed in Table 1, the Ministry of Education has defined CT as "the ability to efficiently solve every problem based on basic concepts and principles of computing" in a large framework of "thinking like a computer scientist." As the goal of SW education, CT competence is expanded into various perspectives, and a teaching and learning method is subdivided for stably applying SW education based on CT in the education field [18], [19].

TABLE I
Definition of Computational Thinking

SW competence	Computational Thinking (CT)	
	Problem-solving elements	**Content**
Analytical skill	Data collection	Collecting data or information required for solving a problem
	Data analysis	Understanding given data, finding patterns, and deducing conclusions
	Data representation (structurization)	Visualizing a problem in graphs, charts, and images
Modeling skill	Problem decomposition	Dividing a large problem into solvable smaller problems
	Abstraction	Simplifying into only the elements absolutely required for solving a problem
	Pattern recognition	Recognizing a pattern that repeatedly appears in the problem-solving process
	Algorithm	A series of processes for solving a problem
Implementation skill	Coding	Solving a given problem using programming languages
	Simulation	Executing a program
Generalization skill	Application and generalization	Applying the problem-solving process to other problems

However, if CT is extensively subdivided in its definition, the goal of each subject may be difficult to achieve [20]. Therefore, the Ministry of Education is striving to apply SW education with flexibility to develop students' problem-solving skills based on CT [21],[22].

3) K-12 information education curricula in Korea: Table 3 shows the problems and comparison between the 2015 revised information education curricula for elementary to high schools implemented since 2018, and the 2022 revised curricula implemented in 2025 [23]. As shown in Table 2, SW education became mandatory for the seventh grade in 2018, and the education target was then expanded to the fifth and sixth grades. From the largest scope, the curriculum includes "Basic Principles of AI," "Programming," "AI Utilization," and "Ethics in AI" and incorporates interconnection between different contents. The Ministry of Education plans to increase the number of leading schools to expand AI education and will apply "Introduction to AI" and "AI Mathematics" as elective subjects for career path decisions in high schools starting from 2024 [24].

TABLE II
CONTENT, CHARACTERISTICS, AND PROBLEMS OF 2015 REVISED INFORMATION EDUCATION CURRICULA FOR ELEMENTARY TO HIGH SCHOOLS

2015 Revised Information Education Curricula for Elementary to High School Implemented Since 2018			
Category	Fifth and sixth grades	Middle school	High school
Content	Total of 17 h as a chapter of a practical course	Total of 34 in information subjects	General elective course in information education
Characteristics	0.28% of total instructional hours in elementary schools	1% of total instructional hours in middle schools	Not reflected in the college entrance process
Problem	Lack of practical training opportunities	Insufficient opportunities to learn data and algorithm	Lack of opportunities to receive information education because of schools without a relevant curriculum

TABLE III
2022 REVISED INFORMATION EDUCATION CURRICULA FOR ELEMENTARY TO HIGH SCHOOLS

2022 Revised Information Education Curricula for Elementary to High School Being Implemented in 2025			
Category	Elementary school	Middle school	High school
Content	Reflect concept/principle of the new technology industry such as AI in information education classes	In-depth learning of AI New classes on information	New classes on various new technologies such as AI and big data

According to the 2015 revised information education curricula for elementary to high schools that has been implemented in 2018, the fifth and sixth grades do not have an opportunity for practical training because only 0.28% of the total instruction hours in elementary schools is assigned for information education, while only 1% in middle schools. Furthermore, information education is a general elective course in high schools, where most schools have not established classes on information education. Therefore, the most important issue with developing computer education talents in Korea is that more than 90% of first-year students majoring in information science-related fields have not learned CT skills, thus having difficulty when taking programming classes [25],[26].

Other countries including the United States, the United Kingdom, and China are currently cultivating AI and SW specialized instructors with creativity and CT-based problem-solving skills, with the U.K. having designated CT as a required course since 2014, where a computing course is offered for an hour per week for 12 years in school. However, there is a clear lack of computing courses in the curriculum in Korea, causing students to first encounter programming after entering universities; additionally, practical training related to SW is mostly provided, which is insufficient for students to gain CT knowledge [27], [28].

Most universities in Korea are providing courses on CT such as the basics of programming and AI convergence coding mandatorily. However, the curriculum is designed particularly for non-computer science majors, "excluding computer science majors from acquiring the same knowledge Learning CT is particularly important for students majoring in computer science for SW education to further advance in Korea. An effective teaching and learning method must be suggested for strengthening CT competence in computer science majors [29],[30]. Therefore, this study surveyed the perception of CT among first-year students majoring in computer science to propose solutions for current problems.

B. Research Method

1) Necessity of research: For the development of SW education, differentiated CT education for students majoring in computer science is required in universities. However, current CT education offered for university computer science majors is inadequate as the curriculum is designed specifically for non-computer science majors. Thus, to improve CT education for computer science majors, this study conducted a survey on the necessity and perception of CT among the students majoring in computer science and proposed a direction for future education.

2) Data collection: This study targeted 313 students who entered universities in 2023 as a freshman and majoring in computer science. Among 313 computer science majors, 200 (63.9%) students were male while 113 (36.1%) students were female, thus demonstrating a higher participation rate of male students.

3) Research tool: The survey used in this study was first developed by Wu and has been modified to fit the purpose of this study [31]. The survey consisted of questions on computer/information literacy and CT education experience before entering universities, six questions on the perception of CT, 11 questions on the necessity of CT, and one question on the improvement of CT education. The responses for the perception of CT include "Agree," "I do not know," and "Disagree," while the questions on the necessity of CT education are scored using a 5-point Likert scale. The survey used in this study was scored based on a 5-point scale.

III. Results and Discussion

A. Computer/Information literacy and CT of students Education Status

The results of conducting a survey on the learning experience of CT among freshmen majoring in computer science at University A in 2023 are listed in Table 4. For the question on their experience of taking classes on "Information" or "Introduction to AI" before entering universities, 175 students (55.9%) among 313 students responded that they had experience in taking classes on "Information" or "Introduction to AI" while 138 students (44.1%) responded that they had on related experience.

TABLE IV
SURVEY RESULTS OF THE CLASSES ON "INFORMATION" AND "INTRODUCTION TO AI" BEFORE ENTERING UNIVERSITIES

Survey question	Yes	No
Have you taken any classes on "Information" or "Introduction to AI" before entering university?	175 (55.9%)	138 (44.1%)

As listed in Table 5, among 175 students who had experience in taking classes on "Information" or "Introduction to AI" before entering universities, 115 students (65.7%) responded their experience period was "less than a year," accounting for the highest portion, followed by 39 students (22.3%) having "less than two years," 15 students (8.6%) having "less than three years," and six students (3.4%) having "four years or more" of experience.

TABLE V
TOTAL EDUCATION PERIOD OF CLASSES ON "INFORMATION" OR "INTRODUCTION TO AI"

Survey question	< 1 year	<2 years	<3 years	≥4 years
How long is the total education period?	115 (65.7%)	39 (22.3%)	15 (8.6%)	6 (3.4%)

As listed in Table 6, the types of programming languages that the students learned during the indicated period were surveyed, and 90 students (51.4%) responded "Python," 71 students (40.6%) responded "C," 53 students (30.3%) responded "Scratch," and 28 students (16%) responded "Entry," while others had also learned "Java" and "Arduino."

TABLE VI
PROGRAMS THAT STUDENTS HAVE AN EXPERIENCE OF LEARNING

Survey question	Python	C	Scratch	Entry
Which programming language did you learn?	90 (51.4%)	71 (40.6%)	53 (30.3%)	28 (16%)

B. Students' Basic Perception of CT

The status of the students' acquiring knowledge related to CT was analyzed as listed in Table 7. The results showed that 177 students (56.5%) among 313 students responded "I do not know," followed by 111 students (35.4%) who responded "Agree," and 25 students (7.9%) who responded "Disagree."

TABLE VII
SELF-EVALUATION ON THE DEFINITION OF CT

Survey question	Disagree	I do not know	Agree
I know what CT is well enough.	25 (7.9%)	177 (56.5%)	111 (35.4 %)

As listed in Table 8, the students' interest in CT was analyzed, and 142 students (45.3%) responded "Agree," 135 students (43.1%) responded "I do not know," and 36 students (11.5%) responded "Disagree."

TABLE VIII
SURVEY RESULT OF STUDENTS' INTEREST IN CT

Survey question	Disagree	I do not know	Agree
I am interested in computational thinking.	36 (11.5%)	135 (43.1%)	142 (45.3%)

The students' opinion on whether CT is the ability to think like a computer was analyzed as listed in Table 9. The result showed that 136 students (43.4%) responded "Agree," followed by 124 students (39.6%) who responded "I do not know," which did not vary significantly from the number of students who responded "Agree," and 53 students (16.9%) who responded "Disagree."

TABLE IX
SURVEY RESULT OF WHETHER CT HAS THE ABILITY TO THINK LIKE A COMPUTER

Survey question	Disagree	I do not know	Agree
Computational thinking is the ability to think like a computer.	53 (16.9%)	124 (39.6%)	136 (43.4%)

The students' opinion on whether CT is the ability to use various programming languages was analyzed as listed in Table 10. The result showed that 190 students (60.7%) responded "Agree," accounting for the highest portion, followed by 90 students (28.7%) who responded "I do not know," and 33 students (10.5%) who responded "Disagree."

TABLE X
SURVEY RESULT OF WHETHER CT IS THE ABILITY TO USE PROGRAMMING LANGUAGES

Survey question	Disagree	I do not know	Agree
CT is the ability to use various programming languages.	33 (10.5%)	90 (28.7%)	190 (60.7%)

The students' opinion on whether CT has the ability to create and utilize documents and presentations was analyzed as listed in Table 11. The results showed that 190 students (60.7%) responded "I do not know," 90 students (28.7%) responded "Agree," and 33 students (10.5%) responded "Disagree." Because most of the students are uncertain, it implies that the definition of CT has not been established properly.

TABLE XI
SURVEY RESULT OF WHETHER CT HAS THE ABILITY TO CREATE AND UTILIZE DOCUMENTS OR PRESENTATIONS

Survey question	Disagree	I do not know	Agree
CT is the ability to create and effectively utilize documents or presentations.	33 (10.5%)	90 (28.7%)	190 (60.7%)

The students' opinion on whether CT assists solve any type of problem was analyzed as listed in Table 12. The result showed that 168 students (53.6%) responded "Agree," followed by 104 students (33.2%) who responded "I do not know," and 41 students (13.0%) who responded "Disagree."

TABLE XII
SURVEY RESULT OF WHETHER STUDENTS CAN SOLVE PROBLEMS USING A COMPUTER

Survey question	Disagree	I do not know	Agree
Excellent CT competence will assist solve any problems using a computer.	41 (13.0%)	104 (33.2%)	168 (53.6%)

C. *Students' Perception of the Requirement of Computational Thinking*

According to the results listed in Table 13, students had an average score of 4.2 points for the statement "CT will be required for most occupations in the future" and an average score of 4.0 points for the statement "I think CT is helpful when solving a variety of problems." The students had an average score of 3.9 points for the statement "I want to take courses on CT," indicating that even those majoring in computer science require proper education on CT.

TABLE XIII
PERCEPTION OF THE REQUIREMENT OF COMPUTATIONAL THINKING

No.	Survey question	Average
1	CT is the thinking skill required for everyone.	3.6
2	CT is the thinking skill only required for computer-related specialists.	2.3
3	CT is the thinking skill that must be taught in elementary to high schools mandatorily.	3.7
4	CT will be required for most occupations in the future.	4.2
5	I want to take courses on CT.	3.9
6	I think CT should be a required course for all university students.	3.6
7	I think CT is more important than other general required courses.	3.6
8	I think learning CT is beneficial for other subjects as well.	3.9
9	I think CT is helpful when solving a variety of problems.	4.0
10	I want to learn CT professionally.	3.5
11	I think CT competence naturally improves if a course on programming is taken.	3.8

The students had an average score of 3.8 points for the statement, "I think CT competence naturally improves if a course on programming is taken." However, this study discovered that CT competence cannot be improved through practical training instead of theoretical concepts.

IV. CONCLUSION

This study conducted a survey on the perception of CT, which has been stressed as the core competence of future SW education in Korea, among freshmen who entered universities in 2023 and are majoring in AI- or SW-related fields, and comparatively analyzed the survey results. First, more students had experience taking courses on "Information" and "Introduction to AI" before entering universities than those who did not, but most of the students who had such experience had less than a year of learning experience. Second, 177 students out of 313 responded "I do not know" to the question on the definition of CT, which is statistically significant. Third, a large number of students agreed that all university students must take a course in CT and wished to take related courses. In addition, the majority of the students agreed with the statement, "I think CT competence naturally improves if a course on programming is taken." According to the survey results, a significant number of students did not have a well-established definition of CT. Instead of continuing their education based on the assumption that computer science major students naturally acquire CT-related knowledge, learning opportunities for CT, which is the basic knowledge of computer and network application programs, should be provided to computer science major students while offering systematic learning methods and environments. Research is actively being conducted on CT education for non-computer science major students as well as CT curricula for elementary to high schools; however, the expansion of CT education must be considered for computer science majors who require it the most.

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