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# Informatics and Artificial Intelligence (AI) Education in Korea: Situation Analysis Using the Darmstadt Model

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***Abstract*— The Korean government has implemented various policies to support software (SW) and artificial intelligence (AI) education to secure national competitiveness since 2015. As the social impact of AI technology increased, AI became an integral component of the computer education curricula. SW and AI education projects have been promoted jointly to develop technical and human infrastructure supporting the "informatics"—the subject name of computer science (CS) education in Korea. However, a survey conducted by the Korean government showed that only a few respondents had AI education provided by public institutions such as schools. Therefore, this paper analyzes why AI education has not been well implemented and proposes discussions for improvement. The Darmstadt model, a systematic framework for analyzing CS education in the country, was chosen to analyze the documents. Between 2015 and 2021, 72 documents related to the computer education system, sociocultural factors, curricula, policies, teaching environment, tests, extra curriculum activities, and media were collected and qualitatively analyzed. The results were presented regarding the educational system, sociocultural factors, curriculum, policies, teachers, tests, extracurricular activities, and media. The results reveal that systematic and coherent curricula are required at all school levels, and it is also necessary to secure more education time to implement the curriculum. The number of informatics-computer teachers should be increased, and research to verify the teaching capacity of teachers is demanded. Finally, it is vital to build and manage a technical infrastructure.**

***Keywords*— AI education; computer science education; informatics education; systematic literature review; Darmstadt model**

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## I. INTRODUCTION

Artificial intelligence (AI) imitates the human thinking process and tries to perform the same intellectual functions as humans. Because of the development of technology, it can process a significant amount of data faster than humans. People living in an intelligent information society are experiencing real-time changes in all areas due to AI.

In 2021, the Korean government conducted "A Survey on the Perception of the Use of AI" on 3,500 people aged 14 to 65 years. The survey revealed that 99.3% of the respondents were aware of AI, and more than 70% had experience using AI products and services. However, only 22.9% of the respondents said they used AI products and services well. The respondents cited the "lack of AI education" as one of the obstacles to the popularization of AI. Of the respondents, 52.8% had no education experience, and only 21.2% had education provided by public institutions such as schools [1]. AI education has been promoted as an important policy to raise people's ability, especially students, to understand and use AI in their day-to-day lives. However, the findings raised questions and concerns about the current situation of AI education.

The need for AI education has changed education policies in many countries, which actively established policies to cultivate AI talents in cooperating industries, schools, and research institutes. For example, the United States has announced the "AI4K12 Initiative" to promote school AI curriculum guidelines, teaching and learning materials development, and teacher support [1]. Since 2017, China has actively researched AI education, emphasizing the necessity of systematic AI education at all school levels through the "Next Generation AI Development Plan" [1]. The UK and Japan included AI education as an essential subject starting from elementary schools. In particular, Japan showed its willingness to foster AI education by establishing "information science" courses for university entrance [2].

The Korean government also announced national policies for introducing AI education in 2019 and added AI-related subjects through curriculum revision. However, the survey showed that AI education was not appropriately implemented. Therefore, this study aims to analyze the status of AI education in Korea using the Darmstadt model (DM) and suggest future directions. To this end, we also analyze informatics education because it has been promoted based on Korea's software (SW) education policies. Since 2015, the Korean government has announced various SW projects to secure national competitiveness in the fourth industrial revolution society. The government's efforts were reflected in the 2015 revised curriculum in the field of education, ensuring the amount and quality of informatics education in schools. AI education policies have been promoted as part of SW education policies, and informatics and AI education policies are closely linked. Hence, if informatics and AI education are analyzed together, the current situation, cause, and improvement direction of AI education can be examined from a wider perspective. As the Korean government is now preparing a new national curriculum, which will be applied in 2025, it becomes more appropriate to analyze the status of Korean informatics and AI education and provide suggestions.

## II. Materials and Method

### A. Research Framework for Computer Science (CS) and AI Education: Darmstadt Model

The DM is a framework developed to standardize and analyze data related to CS education in various countries [3]–[5]. It was produced by the WGISE of the ACM-ITiCSE conference held in Darmstadt, Germany, in June 2011. The DM was developed in 1962 by improving the Berlin model (BM) proposed by Paul Heimann. The BM is a framework focused on generalizing case studies and applying them to classrooms. It tried to classify the context of the classes in detail in the following categories by creating as detailed categories as possible. "Precondition" was divided into artificial preconditions as individual and sociocultural conditions that affect learning; "Decision area" was classified into the curriculum's intention, contents, teaching method, and media. "Result" was described by dividing it into individual and sociocultural results similar to preconditions. However, when CS education was classified according to BM, it was not enough to reflect various experts and stakeholders in the categories because they were not sufficiently subdivided. Also, the coding matching rate between different coders was low, and the DM reconstituted to a new dimension appeared to solve this problem. The DM with more appropriate subcategories has emerged [3]. It is helpful for researchers who want to compare the current status and effectiveness of CSE in various countries and obtain implications [4]. The DM provides as many categories as possible to analyze the country's CSE to help compare it with others [3], [5].

The DM consists of three dimensions [4].

- Dimension 1: "Level of Response/Range of Influence" determines the decision-makers responsible for various levels of education. The following subcategories are suggested: student, classroom, school, region, state, country, and international.
- Dimension 2: "Berlin Model Top Dimension" includes prerequisites for learning, decision areas, and learning outcomes: preconditions, decision areas, and consequences.
- Dimension 3: "Educational Relevant Area" is divided into 13 subcategories related to educational activities. It comprises the original BM's subcategories and several categories that emerged during coding: educational system, sociocultural-related factors, policies, teacher qualifications, motivation, intentions, knowledge, curriculum issues, examination/certification, teaching methods, extracurricular activities, media, and outcomes/effects.

### B. Related Works on the DM

Hubwieser [4] described the case of "The Bayern Project" applying CS mandatory subjects as DM. It was conducted on the students who had completed or graduated from the mandatory, intensified elective courses. This has made the dimension of DM more concrete and elaborate. Gülbahar et al. [6] used DM to analyze the CSEs of Venezuela and neighboring countries. The changes in social and economic conditions in Latin America explored the impacts CSE had on the country and revealed that it needed changes in politicians, universities, and schools rather than technological infrastructure. Raman et al. [7] used DM to analyze the reasons why Indian CS education was not adopted as a core subject. The data from middle school students and teachers of 332 schools were analyzed to find the causes regarding infrastructure, necessity awareness, teachers, and curriculum, and a specific plan to solve them was presented. Choi et al. [8] analyzed CSE in Korea using the DM. They systematically analyzed it to determine the cause of the decline of CSE at the time. They reviewed the data on the education system, curriculum, educational environment, teachers, and policies of CSE in Korea until 2013. Based on the data, the factors that influenced the decline of CSE in Korea were identified. Since then, the Korean government has implemented many policies in school education to promote SW education, and this trend is currently leading to AI education.

### C. Methods

The research procedure is as follows. First, we investigated 72 documents related to informatics and AI education in Korea from 2015 to December 2021. MaxQDA, used for DM classification coded these documents. This text corpus coded for each category was qualitatively analyzed and organized. The results and discussion are presented in Section 3.

Considering the contextual factors of this paper, it is necessary to refer to terms called CS, informatics, and AI education. The government has been promoting policies using the term "SW education" to activate CS education. The "SW education" was applied to the "practical arts" curriculum of elementary schools and the "informatics" curriculum of middle and high schools. This paper considers both SW and CS education "informatics." In addition, even though the importance of AI education has increased recently, AI education has still been introduced into informatics subjects except "AI basic" and "AI mathematics," which were newly established in high schools in 2021. Thus, AI-related subjects in high schools are referred to as the name of the subject, and

AI-related education courses in elementary and middle schools are referred to as "AI education" because they do not have the subject yet.

## III. Results and Discussion

### *A. Educational System*

The Korean school system is classified mainly into elementary, secondary, and higher education. Supervised by the Ministry of Education, it is a single-linear system of 6–3–3–4, where all students go to a single school system. Elementary and middle school students receive an education based on the national standard curriculum. High schools are divided into general high schools, special-purpose high schools, autonomous high schools, and specialized high schools. General high schools, which account for the largest portion of all high schools, provide general curricula not limited to specific fields. They are usually organized and aim to provide early training to students in fields such as science, foreign language, arts, and physical education: science high schools, foreign language high schools, arts high schools, and physical education high schools. Autonomous high schools are designated to operate the curriculum autonomously. Compared to general high schools, curricula and bachelor's degrees can be autonomously defined, and various specialized programs are provided. Specialized high schools are established to train vocational talents, such as tourism, multimedia, and beauty schools. Moreover, experience-oriented education, such as field practice, is provided in Fig. 1.

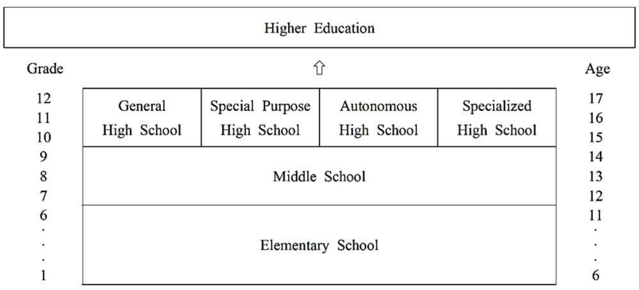


Fig. 1 Korean school system

The curriculum is the center and core of school education because it determines the content and activities of education by realizing its purpose. Therefore, each school sets learning goals and contents based on the national curriculum and selects and provides learning experiences to learners. In Korea, the first national curriculum was enacted in 1954 and revised according to the social changes and demands of the education field. The current 2022 revised curriculum will be developed and applied for the first and second grades of an elementary school in 2024 and will be applied to the first and second grades of middle school and the first grade of high school in 2025.

### *B. Sociocultural-Related Factors*

#### *1) History of Informatics and AI Education in South Korea*

∉ *CS Education in Korea:* The first introduction of informatics-related education into the Korean curriculum was the second curriculum, and there have been many changes from the second curriculum to the 2022 revised curriculum currently under development. The contents of the curricula until 2009 can be found in the study of Choi, Ahn, and Lee (2015). This paper mainly examines the significant changes in characteristics such as the amount of instructional time, subject organization, and learning contents in the 2015 revised and 2022 revised curricula (see Table 1).

TABLE I
History of Computer Education in Korea
(Data derived from the Korea Ministry of Education [9]).

| National Curriculum (Year) | Changes |
|---|---|
| 2nd (1971) | Beginning of computer education<br>Organizing of general subject of electronic calculation |
| 3rd (1974) | From vocational education to general education<br>Reflecting on the "Electronic Calculator" unit in technical subjects |
| 4th (1981) | Designated as an independent subject in vocational high school |
| 5th (1987) | Computer-related content from elementary school to general high school<br>Introducing to high schools as a selective subject<br>Focusing on computer programming in other subject hours |
| 6th–7th (1992) | Independent subject called "computer" in middle school and "information society and computer" in high school.<br>Focusing on ICT literacy |
| 2007 revised (2007) | Changing the name of the subject to "informatics."<br>Focusing on basic concepts and principles of computer science |
| 2009 revised (2009) | Appropriate amount and level of information content<br>Emphasizing algorithmic problem-solving ability and computational thinking |
| 2015 revised (2015) | Reorganizing the science/technology/home economics curriculum into science/technology/home economics/information curriculum<br>Increasing the time for SW education to more than 17 hours in elementary schools and 34 hours in middle and high schools<br>Contents of the curriculum reorganization based on SW education |

∉ *SW Education Operation Guidelines:* The Ministry of Education published Guidelines for SW Education Operation to promote SW education. These guidelines were implemented in schools until 2018 when the 2015 revised curriculum was applied, and the goals, contents, methods, and evaluation directions of SW education were described. In addition, the definitions and components of computing thinking ability were presented so that students could analyze problems and establish solutions based on computing thinking ability.

∉ *The 2015 Revised Curriculum:* The main change in the curriculum was that SW education was essential for elementary and middle schools. In elementary schools, the time for SW education should be more than 17 hours in the "practical arts" subject; the contents consist of play activities and educational tools' programming experiences. In middle schools, the "informatics" subject became mandatory; it should be taught for more than 34 hours. In high schools, the informatics subject was moved from "advanced elective subject" to "general elective subject." The subject was included in the "Science/Technology/Home tutoring/Informatics" subject band in middle and high schools. In addition, the contents of middle and high schools were divided into four areas: "information culture," "data and information," "problem-solving and programming," and "computing systems." The same division of content areas in both schools helped students learn "informatics" systematically and appropriately to their level. As the demand for AI education increased due to the emergence of AI technology, "AI basic" and "AI mathematics" subjects were added to the "elective subject" of high school in 2020.

∉ *The 2022 Revised Curriculum:* The 2022 revised curriculum is currently under development, so the direction and main points of the curriculum were briefly announced. To promote digital and AI literacy, the informatics subject will be expanded. Education about new technologies, such as AI and big data, will be included. The informatics curriculum will be restructured, and the content standards related to digital literacy should be developed in all subject curricula. In addition, it was decided to introduce "data science" and "software and life" as elective subjects in high schools.

Table 2 summarizes the significant changes in the 2015 and 2022 revised curricula. Elementary schools completed informatics-related education in practical art subjects, and middle and high schools opened up informatics subjects reflected in the curriculum. The most significant change in the 2015 and 2022 revised curricula is that the amount of instructional time has dramatically expanded. Elementary schools should complete 34 hours, twice the current number of hours, and middle schools should also complete 68 hours. In the 2015 revised curriculum system, high school students had to complete common subjects (informatics), general elective subjects, and career elective subjects, which are usually subjects. However, according to the revised plan of the high school system, the particular subject that deals with the professional field in the special-purpose high school is incorporated into the normal subject so that general high school students can complete the general selection, career selection, and convergence selection subjects according to their career and aptitude.

TABLE II
COMPARISON OF 2015 AND 2022 REVISED CURRICULA

| **School Level** | **2015 Revised Curriculum** | | | **2022 Revised Curriculum** | | |
|---|---|---|---|---|---|---|
| | Subjects | Compulsory/Elective | Instructional Time (Hour) | Subjects | Compulsory/Elective | Instructional Time (Hour) |
| Elementary | Practical arts | Compulsory | 17 | Practical arts | Compulsory+Elective | 34 |
| Middle | Informatics | Compulsory | 34 | Informatics | Compulsory | 68 |
| High | Informatics | Elective | 85 | Informatics | Elective | 80+a |

Table 3 represents changes in informatics education and AI education selection in high schools. High school "informatics" is a subject that students in general high schools learn and consists of information culture, data and information, problem-solving and programming, and computing systems. It is composed of the same content system to secure the connection with the middle school "informatics." "Informatics sciences" is an intensive subject of "informatics" and has the connectivity of the content system. It is a science-based specialized selection course (intensive selection) taught to students at special-purpose high schools and is divided into programming, data processing, algorithms, and computing systems. All four areas focus on improving the ability to solve real-life problems in various academic fields based on computing thinking.

TABLE III
CHANGES OF ELECTIVE SUBJECTS IN HIGH SCHOOLS

| **Informatics Education** | | **AI Education** | |
|---|---|---|---|
| Informatics | Informatics Sciences | 2015 Revised | 2022 Revised |
| Information culture | Programming | AI basic | AI basic |
| Data and information | Data processing | AI mathematics | Data science |
| Problem-solving and programming | Algorithms | | Software and life |
| Computing systems | Computing systems | | |

In the era of AI-centered digital exchange, AI education was strengthened as the ability to understand and utilize AI was required to solve problems. In the 2015 revised curriculum, "AI basic" and "AI mathematics" were included. The basic principles of AI were easily understood by experience, and "AI mathematics" was composed of systematically learning mathematics that is the basis of AI. The 2022 revised curriculum further organized "data science" and "software and life" into optional subjects so that computing thinking, the core of SW and AI, can be developed.

*2) Personal Factors of the Students:* Students' perception and status of informatics and AI education differed depending on age (i.e., school level) and gender

∉ *Age(School Level):* According to a 2019 survey, elementary school students took the informatics class the most during the sixth grade (58%), middle school students in the first grade (44%), and high school students in the first grade (44.5%) [10]. The survey on the awareness of AI [11] was conducted on 6,324 students (elementary 2,115, middle 3,087, and high school 1,122 students). "Attitude toward AI" refers to students' emotional factors about AI, such as interest, importance, and emotional exchange. The results showed that students with direct and indirect experiences related to AI at all school levels had a more positive attitude toward AI than those who did not. When examined by school levels, the attitudes of middle and high school students toward AI were more positive than those of elementary school students, which was a statistically significant difference. The percentage of students with indirect experience related to AI was higher in middle school students (90.48%) and high school students (91.44%) than in elementary school students (74.52%). The percentage of students who answered that they had direct experience with AI was higher in middle school students (77.33%) and high school students (73.80%) than in elementary school students (61.84%). The direct and indirect experiences of AI affected the awareness of AI, and the attitude of the experienced students toward AI was positive compared to the students who did not have experience, which was statistically significant.

- *Gender:* Kim et al. (2021) concluded that attitudes toward AI differed significantly according to gender, regardless of school levels, and male students were more positive than female students. This was also confirmed because male students had more experience in AI and programming language and more interest in AI [11].

*3) Public Opinion:* This section aims to comprehensively examine the perceptions of students, teachers, and parents on informatics subjects and AI education by synthesizing the surveys' results.

- *Students:* In the satisfaction survey of informatics classes of 5,163 middle and high school students, 51.9% of students answered "satisfaction," 40.7% "normal," and 7.4% "dissatisfaction." The reasons for satisfaction with informatics class were "programming learning," "fun," and "for my job in the future," and the reasons for dissatisfaction were "lack of class time" and "contents were difficult." Also, 50.4% of students were willing to take the class if additional SW- and AI-related classes were open at the school. When asked about what job they want to do for their future, 25.6% of the students said they wanted to have a career related to AI and SW, which was the second most answered [12].
- *Teachers:* Teachers responded positively to the 2015 revised curriculum because the informatics subject turned into a mandatory subject in middle schools. However, 81% of teachers still said that they struggled with a lack of time. To solve these problems, most teachers answered that they needed to execute informatics education from the first grade of elementary school, and the education time should be expanded [13]. As for the time, "informatics" was the only subject in which the curriculum offered the standard time (34 hours). Therefore, there was an opinion that the actual education time was reduced. Before the 2015 revised curriculum, teachers were able to increase class time more freely in the curriculum, but after 34 hours were suggested in the 2015 revised curriculum, teachers usually organized the contents under 34 hours. It is hard to expand class time because of the time presented in the curriculum [10]. In addition, both elementary and secondary school (i.e., middle and high school) teachers responded that technical infrastructure support, such as wireless networks and digital devices in schools, was the most necessary to encourage informatics education. As for AI education, teachers responded that AI-related knowledge is basic literacy and is necessary because it helps students' future career paths. Of the respondents, 31.9% said that AI education should be organized as a necessity for the development of AI education, and 29.6% said that AI education platforms should be developed and operated [14]. Teachers answered that the essential contents for AI education are "AI principle," "problem-solving using AI," and "AI ethics" [12].
- *Parents:* In a survey of 2,383 parents asking whether AI education is necessary, 86.2% of the respondents said that AI-related competence is helpful for their child's future career and is closely related to survival [14]. However, in a survey on participation in private education-related to SW and AI [15], 66.5% of parents said their children took private courses for SW and AI. The highest proportion of the reason was that SW and AI education in schools was insufficient, which 42.9% of parents answered [15]. In other words, many parents think that SW and AI education is lacking in public education.

## C. Policies

### 1) Policies of Informatics and AI Education

- *Basic Plan for SW Education Activation (2016):* To support the necessity of SW education, which was the main task of the 2015 revised curriculum, the Ministry of Education and the Ministry of Science and ICT established human resource and technical infrastructure support plan. The strategies in the plan were to construct technical infrastructure for informatics courses for elementary and secondary schools, foster SW professional talents at universities, and create and promote SW education culture.
- *AI National Strategy (2019):* It was the first national strategy announced by government ministries to respond to the development of AI, and it mentioned AI education for the first time in government policy. They proposed a policy to strengthen computational thinking for all students by 2022 and to expand SW and AI learning opportunities. In elementary schools, the curriculum focused on play and experience was organized to cultivate understanding and interest in SW and AI, and in middle schools, expanded education was implemented so that SW and AI basic literacy could be acquired. In addition, high schools will continue to expand SW and AI curriculum-oriented high schools so that students can voluntarily complete SW and AI enrichment courses.
- *Informatics Education Master Plan (2020):* After executing the 2015 revised curriculum, the government analyzed the performance and limitations of SW education [10]. As a result, the government announced a systematic mid- and long-term plan containing the informatics education's core strategies and tasks. The direction of education was to organize a systematic informatics curriculum at all school levels so that elementary students were able to develop informatics and AI capabilities similar to secondary students. The plan was to expand ICT education for elementary school students, especially informatics and AI education for the fifth to sixth grade band, and informatics and AI competency education for middle school students through informatics courses. As a high school elective course, various subjects related to AI, such as "AI basic" and "data science" were newly established, and "AI convergence high school," a kind of experimental school, was operated. Teachers received a training course to practice convergence education between AI, science, mathematics, and informatics subjects. Lastly, various types of AI education platforms are under development.

- *The Direction and Core Tasks of Education Policy in the Era of AI (2020):* The government presented the direction and core tasks of future education policy with the development of AI and the digitalization of society due to Covid-19. The government suggested introducing AI education to all schools, including kindergartens. AI education will be introduced to the school by 2025. The contents of AI education were proposed, such as “programming,” “AI basic principles,” “AI application,” and “AI ethics.” “AI basic” and “AI mathematics” were introduced as high school career selection subjects, and they were introduced in the second semester of 2021. The Korea Foundation for the Advancement of Science and creativity (KOFAC) developed and distributed four textbooks (two for elementary schools, one for middle schools, and one for high schools) for AI education. In addition, the government was considering including AI-related subjects in their discipline courses to strengthen pre-teachers' ability to teach AI. To encourage the use of big data in education, they organized the “education big data committee.”

*2) Experimental School:* “SW and AI Education Experiment Schools” refer to schools selected to operate various educational programs before executing them in general schools. They seek to identify and promote best practices to spread in regular schools.

- *SW Education Leading School:* Before the 2015 revised curriculum was applied to the field, the government operated “SW education leading school” to start SW education and to find out and spread best practices. The school’s annual operating status from 2014 to 2020 is shown in Table 4.

TABLE IV
THE ANNUAL OPERATING STATUS OF SW EDUCATION LEADING SCHOOLS (ADAPTED FROM THE KOREA FOUNDATION FOR THE ACHIEVEMENT OF SCIENCE AND CREATIVITY [16]).

| Year | Contents | Number of Schools |
|---|---|---|
| 2014 | Introduction of SW education pilot school | 72 |
| 2015 | Launching of SW education leading school | 160 |
| 2016 | Operated jointly by the Ministry of Science and ICT and the Ministry of Education | 900 |
| 2017 | Expanding the number of schools with the demand from the field | 1200 |
| 2018 | Expanding the number of schools to prepare for the application of SW education in the field | 1641 |
| 2019 | Discovering and spreading excellent SW teaching and learning models | 1834 |
| 2020 | Launching AI education leading schools to prepare for AI centered society | 2011 (Including 247 AI education leading schools) |

The main tasks of SW leading schools were to run SW education in the informatics curriculum according to the “2015 revised curriculum” and to run various educational programs in semesters or extracurriculars to develop SW literacy by operating creative experience activities. Therefore, it applied SW education teaching and learning methods, considering the characteristics and level of students. In addition, it held briefing sessions to raise awareness of SW education among students, parents, and local communities through home mail, lectures, and festivals.

- *AI Education Leading School:* The Ministry of Education and the Ministry of Science and Technology (i.e., the Ministry of Science and ICT) have been promoting AI education jointly to introduce it to schools. They selected AI-leading schools among SW leading schools running for more than two years and having the infrastructure needed for AI education. The AI leading school-educated informatics courses as mandatory and operated AI-related clubs. It also operated “AI education experience week” to raise awareness of AI education in local communities. In 2020, 247 of the 2011 SW leading schools were piloted and expanded to 566 in 2021. According to the data compiled and published by the Korea Association of Informatics Teachers in [12], an average AI education time in the AI leading school in 2021 was about 142 hours, which is about 60 hours more than that of general high schools (about 83 hours).
- *Edu-tech Leading High School:* It is an experimental school that innovates teaching and learning by building an educational environment based on cloud computing, a learning management system (LMS), and the Internet of things (IoT) and conducts customized learning for students. More than 30% of all classes should be operated online and offline, and more than eight courses related to AI education were conducted. Ten schools participated in the whole country [17].

### D. Teachers in Korean Schools

#### 1) Certification

- *Teacher Qualifications Act and Recruitment Exam:* Pre-teachers who graduated from teacher colleges or universities of education can get a teaching certificate in Korea if they complete compulsory courses under the “Teacher Qualifications Act.” In addition, aptitude and personality tests, first aid training, and gender equity courses should be completed. However, if they want to be appointed as teachers, they should take the test with their teaching certificates. Each local government decides the number of teachers to be recruited by subject, and the government conducts the recruitment exam. The test includes written examinations for pedagogy and subjects, teaching plans for evaluating teaching ability, functional performance, and interviews. In some private schools, they appointed teachers through separate examination procedures. Teachers who are appointed to public schools in Korea are treated as public officers.
- *Elementary School Pre-teacher Training:* To become an elementary school teacher in Korea, only those who have graduated from the Universities of Education and have a teaching certificate can take the recruitment test. In 2016, the government revised the “Detailed standards for acquiring a teacher certificate” so that pre-teachers could develop informatics education capabilities. Contents related to computer subjects included the curriculum of the Universities of Education, as shown in Table 5.

TABLE V
DETAILED STANDARDS FOR ELEMENTARY SCHOOL TEACHER QUALIFICATIONS

| **Certificate** | Elementary school teacher |
|---|---|
| **Required Subject** | Elementary ethics<br>Elementary Korean<br>Elementary mathematics<br>Elementary society<br>Elementary science<br>Elementary physical education<br>Elementary music<br>Elementary art<br>Elementary practical arts<br>Elementary English<br>Elementary computer<br>Integrated curriculum<br>Elementary safety education |
| **Note** | Including SW-related content in "Elementary practical arts"<br>Including SW literacy, programming, and an algorithm in "Elementary computer." |

*ɇ Secondary School Teacher Training Course:* Korean secondary school teachers can be recruited to schools after the "Teacher Qualifications Act and Recruitment Exam" for candidates who have a second-grade teacher certificate in the subject. Informatics-computer teacher certificates can be obtained when you graduate from the Department of CS Education at the College of Education. If a student majoring in computer engineering receives a high grade and completes the education course together, he/she can get this certificate. Eight universities in Korea have CS education departments, and 200 students graduate each year. In 2014, the course for "informatics-computer" teachers was revised, as shown in Table 6.

TABLE VI
DETAILED STANDARDS FOR "INFORMATICS-COMPUTER" TEACHER QUALIFICATIONS (ADAPTED FROM THE KOREA MINISTRY OF EDUCATION [18])

| **Certificate** | "Informatics-computer" teacher |
|---|---|
| **Before** | Computer education<br>Computer programming<br>Data structure<br>Database, Operating system<br>Computer structure<br>Computer network<br>Information and communication ethics, System programming<br>Logic circuit<br>Algorithm<br>Discrete structure<br>System analysis and design<br>Programming language theory<br>SW engineering<br>AI (over 7 courses out of basic subjects) |
| **After** | (1) Computer (informatics) education theory, programming (essentially)<br>(2) Algorithms, Discrete mathematics, AI (select 1)<br>(3) Data structure, Database (select 1)<br>(4) Operating systems, Networks (select 1)<br>(5) Computer structure, Logic circuit (select 1)<br>(6) Information and communication ethics, SW engineering (select 1) |

Compared to before, it became so systematic because it presented the criteria by field explicitly compared to before. "Informatics education" and "programming" are mandatory subjects to graduate from the Department of CS Education. The remaining 5 subjects must be completed once for each field, from (2) to (6).

*2) Status of Informatics-Computer Teachers:* Table 7 shows the results of investigating the number of informatics-computer teachers in schools and the ratio of teachers for informatics subjects as of December 2020. According to this, the number of informatics-computer teachers in middle and high schools was 0.49, on average, in one secondary school, which was less than one per school. The average number of teachers per middle school was only 0.32 [19]. Due to the lack of teacher supply and demand, teachers who did not have informatics-computer teacher certification were conducting classes. Furthermore, about 30% of the teachers conducting informatics classes in 2020 did not have an informatics computer certificate [19]. There is another way for teachers without an informatics computer certificate to teach the informatics subject. Participating in "multiple major training," which provides classes based on a CS curriculum for 6 months, they are authorized to teach the informatics subject [10]. Teachers who major in similar subjects, such as science and technology, can also conduct informatics classes. Even including teachers who do not have certificates, the average number of teachers was 0.49 per school. Because of the shortage of teachers, 49% of teachers worked in two or three schools in a week [8].

TABLE VII
THE AVERAGE NUMBER OF TEACHERS IN CHARGE OF INFORMATICS SUBJECTS AND THE RATIO OF THE INFORMATICS-COMPUTER CERTIFICATED TEACHERS (ADAPTED FROM THE KOREA EDUCATION AND RESEARCH INSTITUTE SERVICE [19]).

| **School Level** | **Number of Schools (A)** | **Number of Teachers in Charge of Informatics (B)** | **Average Number of Teachers per School (B/A)** | **Number of Teachers Who Have the Informatics-Computer Teacher Certificate (C)** | **Ratio of the Teachers Who Have the Informatics-Computer Certificate Among Teachers in Charge of Informatics (C/B, %)** |
|---|---|---|---|---|---|
| Middle | 3,242 | 1,034 | .32 | 795 | 76.89% |
| High | 2,365 | 1,720 | .73 | 1,189 | 69.13% |
| Total | 5,607 | 2,754 | .49 | 1,984 | 72.04% |

Table 8 shows that the number of pre-teachers with informatics-computer teacher certification was decreasing every year. As informatics education is mandatory in middle schools due to the 2015 revised curriculum, demand for informatics teachers has surged, but the number of pre-teachers trained every year has been decreasing.

TABLE VIII
NUMBER OF UNDERGRADUATE STUDENTS IN COMPUTER EDUCATION IN 2016–2018 [20]

| **Year** | 2016 | 2017 | 2018 |
|---|---|---|---|
| **Number** | 267 | 220 | 206 |

*3) Teacher Training*

∉ *Pre-service Teacher Training:* The Ministry of Education and the KOFAC have promoted the SW Education for all Elementary Teachers (SWEET) project to improve pre-teachers' SW and AI capabilities. Since 2018, the project has included various measures to strengthen SW instruction capacity from preliminary elementary school teachers. The SW-related mandatory was expanded, and the college opened courses that converged with other subjects. In addition, there were competitions and inquiry contests to practice the content they learned, providing opportunities for SW education. The "AI Education Strengthening Support Program" was started in 2021. This program selected some elementary and secondary teacher training institutions and supported the project reorganizing the curriculum centered on AI education. The selected institutions were commonly used to run basic AI courses. "SW Eduton" is a contest where pre-teachers show SW and AI education capabilities. It evaluates their capabilities through class plans and visual images and provides opportunities to strengthen their capabilities through online education and offline mentoring programs.

∉ *Teacher Training:* The "Teacher Training for SW·AI Education Project" is a training course that fosters the capacity of teachers to teach informatics subjects at school. Since 2015, this training curriculum has been developed considering the teacher's school level and SW competency. The content consisted of developing and evaluating teaching and learning models that can effectively implement SW education, which can apply to school classes. In addition, there was an advanced program for teachers with professional teaching and learning competency. There was also a general training program for all teachers. It consisted of content that helped teachers teach the course of SW education based on the textbooks. A survey showed that the average number of teachers trained every year was about 4,000 [16]. Teacher training for AI education was conducted by the Korea Education and Research Institute Service (KERIS) and KOFAC. The training courses were as follows: an experienced course to understand the concept of AI and the principle of movement, a knowledge acquisition course to strengthen students' creative capacity, and a teaching method course to combine AI and subjects. In addition, the "AI Convergence Education Capacity Enhancement Support Project" encouraged admission to the Graduate School of AI Convergence Education. The graduate school curriculum deals with teachers' understanding of AI, AI class design, teaching methods that combine AI and other knowledge, and educational methods that can develop creative problem-solving skills. The project provides 50% of the tuition fee to 1,000 teachers who enter graduate school annually [21].

## *E. Intention*

This section reviews the informatics curriculum's learning objectives, competencies, achievement standards, and content systems in the 2015 revised curriculum. As far as AI education, we review the "AI basic" and "AI mathematics" curriculums added to the 2015 revised curriculum in 2020. In addition, we also examine the "Content Standards for AI Education in Elementary and Secondary Schools" designed by the KOFAC in 2020.

*1) Learning Objectives*

∉ *Learning Objectives of Informatics:* In elementary schools, informatics education is in the sub-areas of technology in practical arts, so the objectives of informatics also belong to the "technical" domain in practical arts. The goals are listed as follows: to develop the ability to solve technical problems, to utilize technology that can be creatively solved and applied to real-life based on understanding technology, and to develop the ability to design a technology system that can actively cope with and adapt to the development of technology and social changes. In middle and high schools, CS education has been taught as an informatics subject. The goals of the informatics subject in middle school are to cultivate basic information ethics and information protection ability and develop information technology utilization ability, computational thinking ability, and problem-solving ability to solve a real-life problem. The goals of the informatics curriculum in high school are to strengthen the capacity to practice information protection based on the awareness of information ethics and to develop the ability to utilize information technology, computational thinking, and the cooperative problem-solving ability for various academic fields as well as real-life problems. Learning objectives of informatics in the 2015 revised curriculum are presented in Table 9.

TABLE IX
LEARNING OBJECTIVES OF INFORMATICS IN THE 2015 REVISED CURRICULUM

| School Level | Grade Band | Subject | Learning Objectives |
|---|---|---|---|
| Elementary | 5-6 | Practical arts | To solve problems creatively and use them in real-life<br>To cope actively with the development of technology and social changes |
| Middle | 1-3 | Informatics | To understand the characteristics of information society and develop proper attitudes to information ethics and information protection<br>To cultivate the ability and attitude of managing and producing information efficiently by utilizing information technology<br>To develop the ability to abstract problems according to the computing principle and the ability to design and implement solutions as SW through programming processes<br>To understand the composition and operation principles of the computing system and to implement a creative computing system that can solve real-life problems |
| High | 1-3 | Informatics | To perceive the value and influence of information science and the attitude of practicing information ethics, information protection, and security<br>To understand efficient digital expression methods and develop the ability and attitude to collect, analyze, and manage data and information using information technology<br>To develop the ability to abstract academic problems according to CS's basic concepts and principles and design and implement solutions as SW through the programming process<br>To develop the ability to understand efficient resource management methods of computing systems and to creatively implement physical computing systems for complex problem-solving in academic fields |

∉ *Learning Objectives of AI Education:* The "Content Standards for AI Education in Elementary and Secondary Schools" proposed the objective of AI education at the school level. The objectives of AI education in elementary schools are to experience the functions and principles of AI through play and educational tools and to explore cases where AI is applied around them. The objectives of AI education in middle schools are to understand the value of data as the driving force of AI development and the principles of AI and to develop the ability to solve real-life problems. In the case of high schools, only the "advanced AI" is presented in this content standard because the "AI basic" subject was developed in 2020. The goals of "advanced AI" are to understand the concept and algorithm of AI of deepened contents based on the contents in "AI basic" and to develop the ability to solve problems by applying AI. The goals of the "AI basic" subject added to the 2015 revised curriculum are to develop AI literacy, AI ethics consciousness, and AI utilization ability based on the basic concepts of CS and to develop the ability to solve problems in real-life and various fields creatively and efficiently based on the basic concepts and principles of AI and the application method of machine learning models. Furthermore, the subject of "AI mathematics" aims to understand how to use mathematics when solving various problems in real life using AI to recognize the value of mathematics and develop the capabilities needed by future society. The goals of AI education are presented in Table 10.

TABLE X
LEARNING OBJECTIVES OF AI EDUCATION

| School Level | Grade Band | Subject | Learning Objectives |
|---|---|---|---|
| Elementary | 5-6 | AI | To experience the functions and principles of AI through play and educational tools<br>To explore cases where AI applied around them |
| Middle | 1-3 | AI | To understand the value of data as the driving force of AI development<br>To develop the ability to solve real-life problems |
| High | 1-3 | AI basic | To understand the value of AI and social changes through AI<br>To cultivate the attitude to cope with actively AI-based society<br>To develop the ability to solve problems in real life based on the basic concepts and principles of AI<br>To develop the attitude and ability to solve various problems using machine learning<br>To develop the attitude to think critically about AI ethics and to implement AI ethics |
| | | Advanced AI | To understand the concept and algorithm of AI for deepened contents<br>To develop the ability to solve problems by applying AI |
| | | AI mathematics | To experience the way to express data mathematically and classify and predict based on data, to determine reasonably through optimization<br>To understand the use and the value of mathematics in AI through mathematical inference and communication<br>To develop the desirable attitude as a mathematical learner |

2) *Competencies*

∉ *Competencies of Informatics:* The 2015 revised curriculum set up competencies for each subject. In the case of elementary school, informatics subject–related contents are part of the "practical arts" subject, so competencies are not presented. However, middle and high schools have informatics subjects, so they could set up their competencies, as shown in Table 11.

TABLE XI
COMPETENCIES OF INFORMATICS

| School Level | Competency | Sub-competencies |
|---|---|---|
| Middle, High | Information culture Literacy | Information ethics consciousness<br>Information protection ability<br>Information technology utilization ability |
| | Computational thinking | Abstraction ability<br>Automation ability<br>Creativity and convergence ability |
| | Collaborative problem-solving | Cooperative computing thinking ability<br>Digital communication ability<br>Sharing and collaboration ability |

∉ *Competencies of AI Education:* The "Content Standards for AI Education in Elementary and Secondary Schools" presented the competencies from elementary schools to high schools, and "AI basic" and "AI mathematics" also presented the competencies to be raised in high schools. These are presented in Table 12.

TABLE XII
COMPETENCIES OF AI EDUCATION

| School Level | Subject | Competencies |
|---|---|---|
| Elementary<br>Middle<br>High | AI education in school | The ability to understand and attitudes toward AI<br>The ability to solve various problems creatively, convergently, and relatively using data and AI |
| High school | AI basic | AI literacy that members of information society should have |
| | AI mathematics | Problem-solving using mathematics knowledge and skills<br>The ability to infer mathematical facts and analyze them<br>The ability to create new and meaningful ideas and converge them with knowledge from other subjects<br>The ability to represent ideas and understand ideas from others<br>Information processing<br>Information processing ability<br>Mathematics learning attitude and the ability to practice mathematical knowledge and value |

### 3) Knowledge and Curriculum Content System

∉ *Content System of Informatics:* In elementary schools, content is the part of the "technical system" area in the practical arts curriculum, as shown in Table 13. Because the content system and composition of elementary schools are different from middle and high schools, the continuity of content is not secured [22].

TABLE XIII
CONTENT SYSTEM OF INFORMATICS IN ELEMENTARY SCHOOLS

| School Level | Subsection | Content |
|---|---|---|
| Elementary | Technical system | Understanding SW<br>Procedural problem-solving<br>Programming elements and structures<br>Protection of personal information and intellectual property<br>Functions and structures of robots |

The content systems of middle and high schools are the same and consist of four parts, as shown in Table 14. "Information culture" provides knowledge of the values and behavior styles that members should observe in the information society, new jobs related to information technology, and information society. "Data and information" provide knowledge of how to express data and information on a computer and collect, analyze, search, classify, process, and structure data and information needed for problem-solving. "Problem-solving and programming" provides knowledge related to abstraction, algorithms, and programming for problem-solving. "Computing system" provides the operating principles and physical computing of computing systems combined with hardware and software. Content elements are provided according to the school level. The content systems of informatics between middle and high schools are systematic because the content systems are the same, and the content elements differ by levels.

TABLE XIV
CONTENT SYSTEM OF INFORMATICS IN MIDDLE AND HIGH SCHOOLS

| Section | Subsection | Content | |
|---|---|---|---|
| | | Middle | High |
| Information culture | Information society | Characteristics and career of information society | Information science and career |
| | Information on ethics | Personal information and copyright protection<br>Cyber ethics | Personal information<br>Copyright use<br>Cyber ethics |
| Data and information | Representation of data and information | Types of data and digital representation<br>Data collection | Efficient digital representation |
| | Analysis of data and information | Data collection<br>Information structure | Data analysis<br>Management of information |
| Problem-solving and programming | Abstraction | Problem understanding<br>Core element extraction | Problem analysis<br>Problem decomposition and modeling |
| | Algorithm | Algorithm understanding<br>Algorithm representation | Algorithm design<br>Algorithm analysis |
| | Programming | Input and output<br>Variable and operation<br>Control structure<br>Programming application | Programming development environment<br>Variables and data type<br>Standard input/output and file input/output<br>Nested control structure<br>Array<br>Function<br>Programming application |
| Computing System | Principle of computing system operation | The construction and operation principles of computing devices | Role of operating system<br>Network environment setting |
| | Physical computing | Sensor-based program implementation | Physical computing implementation |

∉ *Content System of AI Education:* According to the "Standards for AI Education in Elementary and Secondary Schools," AI education contents are divided into three areas. First, "understanding AI" deals with the understanding of AI and agents with AI. Second, "the principles and application of AI" deals with the learning about data, recognition, classification, search, reasoning, machine learning, and deep learning. Finally, "social impact of AI" focuses on exploring ethical issues that may arise in AI society. Details are presented in Table 15.

TABLE XV
CONTENT SYSTEM OF AI EDUCATION IN "STANDARDS FOR AI EDUCATION IN ELEMENTARY AND SECONDARY SCHOOLS."

| Section | Sub-section | Content | | | |
|---|---|---|---|---|---|
| | | Elementary School (1–4 Grade Band) | Elementary School (5–6 Grade Band) | Middle School | High School (Advanced) |
| Understanding of AI | AI and society | The first meeting with AI | Various uses of AI<br>Weak and strong AI | Process of development of AI | Application area of AI<br>Convergence of AI |
| | AI and agent | | | Turing test | Analysis of intelligent agent |
| Principle and application of AI | Data | Various types of data visualization of numerical data | Importance of data<br>Visualization of text data<br>Data tendency | Collecting<br>Data preprocessing<br>Data forecasting | Analysis features of data<br>Big data |
| | Perception | Perception of Computer versus human | Computer recognition | Object detection | Computer vision application |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Voice recognition application<br>Natural language processing |
| | Classification, searching, reasoning | Classifying by features | AI classification<br>Knowledge graph | AI searching<br>Rule-based reasoning | Heuristic search<br>Logical reasoning |
| | Machine learning and deep learning | AI learning play activity | Experiencing<br>Principle of machine learning | Supervised learning<br>Unsupervised learning | Machine learning algorithm<br>Principle of reinforcement learning<br>Perceptron and neural network<br>Deep neural network |
| The societal impact of AI | The influence of AI | AI that helps us | Life with AI | AI and career | Living with AI<br>Algorithm bias |
| | AI ethics | . | The right use of AI | Preventing from misusing of AI | AI developer's ethics<br>AI frontier's ethics |

The high school selection subject "AI basics" is composed of four areas, adding "data and machine learning" to the content area presented in "Standards for AI Education in Elementary and Secondary Schools." In the "data and machine learning" section, the types of data to be used for implementing machine learning models and the contents of machine learning models are discussed and presented in Table 16.

TABLE XVI
CONTENT SYSTEM OF "AI BASIC."

| Section | Subsection | Contents |
|---|---|---|
| Information and culture | AI and Society | Concept and characteristic of AI<br>Development of AI and social changes |
| | AI and agent | Concept and role of intelligent agent |
| Principle and application of AI | Perception | Sensor and perception<br>Computer vision<br>Perception of voice and language |
| | Searching and reasoning | Problem-solving and searching<br>Representation and reasoning |
| | Learning | Concept and application of machine learning<br>Concept and application of deep learning |
| Data and machine learning | Data | Feature of data<br>Formal and informal data |
| | Machine learning model | Classification model<br>Implementation of machine learning |
| The societal impact of AI | AI impact | Societal problem-solving<br>Data bias |
| | AI ethics | Ethical dilemma<br>Social responsibility and fairness |

"AI mathematics" consists of four subsections. "AI mathematics" examines the relationship between AI and mathematics. "Expression of data" deals with how to express the data using mathematical symbols. "Classification and prediction" provides mathematical content AI used to perform classification and prediction. "Optimization" deals with the process of creating and optimizing functions to find the best decision-making model. Finally, "related learning elements" in the system presented the mathematical concepts and principles used in AI learning. Details are shown in Table 17.

TABLE XVII
CONTENT SYSTEM OF "AI MATHEMATICS."

| Section | Subsection | Contents |
|---|---|---|
| AI and mathematics | Mathematics related to AI | Truth table<br>Order chart |
| Data representation | Text data representation<br>Image data representation | Vector<br>Matrices |
| Classification and prediction | Data classification<br>Tendency and prediction | Similarity<br>Trend line<br>Conditional probability |
| Optimization | Optimization and decision making | Limit of function<br>Differential coefficient of secondary function<br>Loss function<br>Slope descent method |

#### 4) *Examination and Certification*

- *Evaluation of Informatics:* Student evaluation is an indispensable component of educational activities. It confirms what students achieved through school education and helps students grow and develop their abilities. Before the 2015 revised curriculum, the evaluation method was the result-based evaluation. However, as the evaluation paradigm changed, the process-based evaluation, which is an evaluation for learning, increased as the capacity of the 2015 revised curriculum was emphasized. In a process-based evaluation for capacity development, the teacher helps the student actively learn as a guide to learning and evaluates all the processes of learning activities. As various evaluation methods were used, the development process of students could be evaluated continuously and comprehensively. In addition, there was a reflection that the existing evaluation in the education system was used only to measure the level of students' sequence to go to college. As a result, "the curriculum-class-evaluation-record integration" appeared to improve the situation where the curriculum, class, evaluation, and record are divided. It restructured the curriculum with the aim of authentic student growth. Based on this, teachers design student participation-oriented classes, evaluate the course of class activities, and record the contents in detail. In other words, the curriculum, class, evaluation, and record table work as one team.
- *College Scholastic Ability Test (CSAT):* Students have a College Scholastic Ability Test (CSAT), a necessary test in addition to school evaluation; it has a significant influence on

university admission. Therefore, most high school's curriculum is organized focusing on subjects reflected in the test, and these subjects belong to "common subject," a compulsory subject for high school graduation. However, informatics-related subjects such as "informatics" and "AI basics" are not tested in the CSAT, are included in the "elective subject", and are not required for high school graduation.

### F. Extracurricular Activities

#### 1) Education for the Gifted in the Informatics

∉ *SW Gifted Class:* The government began education for the gifted in informatics in 1988. Since the enactment of the Gifted Education Promotion Act in 2000, facilities and *support* for gifted education expanded, but the proportion of gifted students who chose informatics subjects was low compared to mathematics and science subjects [23]. However, in 2015, based on the "SW education human resource development plan," a project was launched to help students develop their SW program and capabilities. The goals were establishing classes in each region and identifying and nurturing local SW personnel early. In 2016, 30 classes (18 for elementary and 12 for secondary) were newly designated, and the grants for the school were distributed. By 2020, the government had operated 30 classes, and about 500 students had completed the training. Students learned SW-related advanced curriculum, produced SW work in real life, and announced it through competition. In addition, a workshop was held to share excellent performance and efficient management cases to strengthen the capacity of teachers in charge of SW gifted classes. The result of the satisfaction survey of the operating teachers conducted in 2020 was 90 out of 100. The teachers were satisfied with the online platform support, teacher community, and teaching content. For students who have completed their education in SW gifted classes, their willingness to go to the SW-related field has been relatively high (77 out of 100 in 2020) and steadily rises every year. However, according to the current status of gifted education in 2020, only 0.6% of all gifted education institutions are registered as institutions dedicated to informatics gifted education programs, and the number of information gifted students is just 5.5% of all gifted students [22], [23].

∉ *Korea Olympiad in Informatics:* It is held to discover and foster gifted students in informatics and communication. There are two kinds of competitions: one is to evaluate algorithms and program writing skills that require mathematical knowledge and logical thinking skills. Elementary, middle, and high school students can participate in this. Evaluation of the ability is to write programs that properly use algorithms and data structures; the languages are C/C++ and Python available. The first (regional) and second (national) competitions exist, and explanations of them are in Table 18. Students must solve the problem by using a computer within a given time and receive a high score if the student solves the problem efficiently. The other competition is a contest to compete and examine creative SW works. SW works with originality get a good evaluation.

TABLE XVIII
STEPS IN KOREA OLYMPIAD IN INFORMATICS

| Steps | Content |
|---|---|
| First competition | A regional competition<br>3 types of questions (Thinking Problems, Bebras Challenges, Practical Problems) |
| Second competition | A national competition<br>C/C++, Python, and Java are available in the Google Chrome environment of Windows<br>Using CMS system for real-time scoring |

∉ *AI Gifted Class:* Since 2019, AI gifted classes have been operating along with SW gifted classes; 100 hours of SW advanced education and the contents of AI and big data are provided to students. Since 2021, 22 classes have been promoted to support programs and faculty members in connection with schools, universities, and industries. According to the "informatics education master plan," the competent schools among the existing schools for SW gifted are selected and supported as "AI talent training schools." The school operates two educational programs: the program for developing research capabilities at the University of Science and Technology Specialization and the program for teaching entrepreneurship from major domestic IT companies by major domestic companies. In addition, the "Informatics and AI Gifted Growth Program" runs only for students from gifted schools and science high schools to cultivate talented students with AI-related capabilities. Students who attended and won the prize or by teacher's observation have been recognized for their outstanding abilities in informatics and AI. These students can get expert mentoring and joint research opportunities for AI to foster their research and development capabilities.

#### 2) Festival and Contest

∉ *SW Education Festival:* It is an event that provides various SW education experience opportunities to promote and activate SW education in society. Since 2015, the government, schools, and companies have organized events to hold SW education-related experience activities and seminars every October. The main programs are as follows: introduction of SW education tools, an exhibition to experience new technologies, expert lectures, SW-related career shows, talk concerts, and programs for teachers from global companies such as Google and Microsoft. In addition, a variety of contests such as "SW Eduton," "Korea code fair," and "Online coding party" are held. The number of visitors is about 50,000, and the number of participating organizations and festival programs continues to increase every year. In 2019, 167 participating organizations and 158 programs participated [16].

∉ *Online Coding Party:* It started in 2015 and has operated an event in which anyone can experience SW-related education. The event runs for two seasons each year. Anyone interested in SW can participate in and enjoy various programs of block coding, text coding, and computational thinking. About 380,000 people participated in 2016, and more than 1 million people participated in 2018. However, about 660,000 people participated in 2020, reducing the number of participants. In 2020, they added AI programs, creating an opportunity to become familiar with AI education.

∉ *Korea Code Fair:* It is a youth-targeted computer programming competition hosted by government agencies on cloud platforms; the competition's programs consist of three. First, the "SW Competition" is a competition for SW works that combine technologies with various problems in society, life, and the environment. As an individual or team, students participate, and if they receive excellent results through the first and second exhibitions, they can get the chance to participate in the International Science and Technology Competition. "SW Hackerton" is a competition to draw solutions by using SW algorithms for the presented question. Approximately 100–150 teams of students are selected and educated. The standards of the competition are creativity, effectiveness, appropriateness of implementation of works, and completeness. "Online SW Study Room" allows students to measure their levels by learning SW and solving problems online.

∉ *Bebras Challenge:* It is a problem-solving based evaluation model developed to induce students to learn about CS and develop computing thinking ability. Starting in Lithuania, 69 countries worldwide jointly develop and disseminate problems, study teaching and learning, and evaluate methods. After participating in the demonstration led by the Korea Information Science Society in 2016, 7,203 students participated in official member countries in 2017. In 2020, the Korea Bebras Challenge was held in Korea by a nonprofit organization organized by teachers and professors. According to a study that examined the link between the Bebras Challenge questions and the informatics curriculum, it was appropriate to use the Bebras Challenge questions to evaluate the curriculum [24].

∉ *Online Judge:* It is one of the automatic evaluation systems used in programming education. It compiles and executes the source code submitted by the learner in the same environment and automatically evaluates the accuracy and efficiency of the source code. As the teaching and learning method of the 2015 revised curriculum recommended the use of an automatic evaluation system, high school information teachers developed some online *judgment* systems, which have been widely used in performance evaluation in high school programming classes. Domestic online judge systems developed by schools and teachers are listed in Table 19 [25].

TABLE XIX
ONLINE JUDGE SYSTEM DEVELOPED BY SCHOOLS AND TEACHERS IN KOREA

| Name | Language | URL |
|---|---|---|
| Codeup | C, C++, Python, Java | Codeup.kr |
| Koistudy | C, C++, Python, Java | Koistudy.net |
| Judgeon | C, C++, Pascal, Java | Judgeon.net |
| Coding is fun | C, C++, Python, Block | Codingfun.net |
| Judge in Koreatech | C, C++, Java | Judge.koreatech.ac.kr |

∉ *AI Youth Challenge:* It has been an AI competition for young people sponsored by the Ministry of Science and ICT since 2020. Middle and high school students interested in AI can participate nationwide as individuals or in teams. The theme that emphasizes the positive role of AI is presented differently every year, and accordingly, works that suggest ideas and works that apply AI are exhibited. There is no restriction on the programming language or hardware used for an idea and work performance, and it provides opportunities for students to elaborate and grow their ideas through expert mentoring and sharing them.

∉ *AI Festival:* It was held for the first time in 2021 and jointly organized by local government and 20 science-related government research institutes. It is a program that can explore the relationship between AI, education, business, and meta bus. It provides expert lectures, quiz programs, talk concerts, and project experiences. The festival was conducted both online and offline. Participants were able to experience the program and interact with each other by using live broadcasting and a meta bus.

### *G. Media*

*1) Textbooks*: In Korea, textbooks are published through strict standards by the law to improve the quality and utility of education because they are closely related to the national curriculum. Private publication companies produced practical arts and informatics textbooks, and the Ministry of Education or public institutions approved them after the suitability examination. The school selects one textbook for students among the approved books.

∉ *Informatics Textbooks*: In elementary schools, six textbooks are approved. All textbooks present content on informatics in the sixth grade. There are two parts of the content: SW and physical computing. The contents of SW were composed of an understanding of SW, procedural thinking, and programming as a large unit, and the contents of physical computing as a small unit. All six textbooks arrange the contents in 17 hours, which contrasts with the development of middle school informatics textbooks 68 times, even though the standard time is 34 hours [26]. In middle schools, 17 informatics textbooks were approved for use in schools. They were composed of four units according to the content system of the curriculum. By organizing a large amount of "problem-solving and programming" units compared to other units, they were focused on the development of computational thinking ability. Eight books were approved for high school informatics textbooks and have been used in schools since 2018. The area of "problem-solving and programming" was also emphasized, similar to the middle school textbooks.

∉ *AI Education Textbooks:* "AI basics" and "AI mathematics" were added through the curriculum revision in 2020. There are seven "AI basics" textbooks. The textbooks were composed of four major units: "understanding AI," "principles and application of AI," "data and machine learning," and "social influence of AI" according to the content system in the curriculum. In addition, there are five "AI mathematics" textbooks approved. They are also composed of four large units: "AI and mathematics," "expression of data," "classification and prediction," and "optimization". In addition, AI-related subjects were developed in high school "career selection subject," including "AI and future society," "information task research," "data science and machine learning," "Internet of things," "AI and physical computing," and "mathematics and AI". The textbooks for these subjects were made with the approval of each local government.

∉ *AI Education Support Materials:* In the "Education Policy Directions and Core Tasks in the Artificial Intelligence Era: The Future of Education in Korea," the contents of AI education were announced, and books *were* developed to fill the gap in AI education before the 2022 revised curriculum. "AI education in school" was developed by the Ministry of Education and the KOFAC: two for elementary schools, one for middle schools, and one for high schools. These textbooks were provided as PDF files on the Internet. The textbooks consisted of four units: "understanding AI," "principles and application of AI," "social impact of AI," and "project" units. The "principles and application of AI" part for middle and high schools was divided into two units because a large amount of it was organized in the textbooks. The unit of "project" was organized to allow students to do their works using AI.

*2) AI Education Platform*

∉ *AI Education Contents Platform:* AI education materials platform operated with the SW education platform. State agencies or public institutions mainly manage it, and its details are in Table 20.

TABLE XX
AI EDUCATION MATERIALS PLATFORMS

| Name | Content |
|---|---|
| SW-centered society | SW- and AI-related educational materials, career information, industrial information, support policies |
| Play with SW | Operated by "Naver connect Foundation"<br>Online training courses and materials on AI, data, and SW<br>Provides practice program (Entry) |
| ESOF | Operated by Korea Educational Broadcasting System<br>Online training courses related to SW and AI by level<br>Teaching and learning materials for the class |
| Edunet | Operated by the KERIS<br>Teaching and learning materials for AI education<br>AI experiment school education plan and report<br>Content recommendation system using big data |
| AI hub | Learning contents reconfiguring the conference problem for learning<br>Level-specific program<br>Data utilization available |

∉ *Education Platform for AI Practice:* There are six platforms that are popular for practicing AI in school: "Entry," "ML for Kids," "Teachable Machine," "AI Oceans," "App Inventor," and "mBlock" [27]. In this section, we focus on the domestic platforms: "Entry," "Genie Block," and "Elice." "Entry" is an SW practice platform in practical arts textbooks in elementary schools. As the AI function was added to "Entry," it has been widely used for AI practice in schools. It provides AI models and big data within the platform. "Genie Block" is a company-made platform that can use the AI Maker Kit, which enables basic programming and voice recognition. Students can experience AI easily in conjunction with the speakers provided in the kit. "Elice" is a platform created by a startup company and is a text coding platform based on the Python platform. It provides a course for developing a deep learning program that processes images and natural words using tensor flow and provides a practical program that can utilize machine learning algorithms that match the given data as an intensification process. The contents of comparing the platforms are given in Table 21.

TABLE XXI
EDUCATION PLATFORM FOR AI PRACTICE

| Name | Type of Programming | Content |
|---|---|---|
| Entry | Block-based, Text-based | Data analysis function<br>Image, text, voice recognition function<br>Machine learning model (supervised, unsupervised) production function |
| Genie Block | Block-based, Text-based | AI education using voice recognition tool<br>AI experiences available for young students |
| Elice | Text-based | Python-based platform<br>Development of deep learning program using tensor flow<br>Advanced practice courses related to machine learning algorithms |

∉ *AI Education Platform for Everyone:* The government established an "AI education platform for everyone" providing the principles of AI, machine learning, and data science. The main contents include the basic concept of AI, project-oriented experiments, practice systems, and community functions capable of answering questions. It will also provide a data factory containing datasets. The platform began to be constructed in 2021 and aims to be completed by 2024.

*3) Learning Management System (LMS):* It is a system that supports and manages learners' learning. The system provides customized education by reflecting learners' learning information. LMS developed in Korea includes "ESOF," "E-learning center," "EBS online class," and "Knock-Knock! Math Expedition." "ESOF," "E-learning center," and "EBS online class" played a role in facilitating home learning. Details related to LMS developed in Korea are summarized in Table 22.

TABLE XXII
LMS PLATFORM BUILT IN KOREA

| Name | Content |
|---|---|
| ESOF | Information for customized self-directed learning |
| E-learning center | Online learning platform for elementary and middle school students<br>A system for conducting online lessons<br>Approximately 3.6 million subscribers in 10,000 schools<br>All content is provided free of charge |
| EBS online class | Online learning for elementary, middle, and high school students<br>Approximately 2.4 million people from 11,000 schools joined<br>Video lecture, two-way communication function added |
| Knock-Knock! Math Expedition | The first case of introducing AI into school education<br>Analysis and prediction of students' learning information with AI<br>Learning content recommendations<br>The experimental school has been in operation since March 2019 |

*4) Technical Infrastructure:* In this section, we examine the status of technical infrastructure in schools. The government announced a plan to construct technical infrastructure for SW education in 2016. Several strategies were executed: installing computer rooms, replacing aged devices, introducing wireless Internet, and distributing smart pads. We investigate how digital devices currently owned by schools, wireless Internet networks installed, and labs are established.

∉ *Lab Establishment:* Lab refers to a room for digital devices, such as a computer or multimedia room. In 2018, the Ministry of Education announced that at least one lab per school was installed except for about 1.7% of elementary and middle schools nationwide [10]. Schools without labs planned to install a lab or provide alternative facilities (e.g., distribution of smart pads). As a result of examining the status of labs in schools shown in Table 23, the average lab per school was 1.36 in elementary schools, 1.08 in middle schools, and 2.11 in high schools. However, considering computer rooms, except for multimedia rooms, the average number of middle schools was 0.87, less than one lab per school [28].

TABLE XXIII
NUMBER OF LABS PER SCHOOL IN 2020 (ADAPTED FROM THE SOFTWARE POLICY AND RESEARCH INSTITUTE [28]).

| **School Level** | **Number** | | | | |
|---|---|---|---|---|---|
| | **Computer Room (A)** | **Multimedia Room (B)** | **School (C)** | **Lab per School ((A+B)/C)** | **Computer Room per School (A/C)** |
| Elementary | 7.848 | 755 | 6.333 | 1.36 | 1.24 |
| Middle | 2.831 | 672 | 3.256 | 1.08 | .87 |
| High | 3.220 | 1.786 | 2.368 | 2.11 | 1.36 |

∉ *Digital Devices:* Types of digital devices include desktop PCs, laptops, and smart pads. According to the study, an *average* of five students were allocated per device. Only one digital device per five students, on average, was distributed, which seemed to be far from enough to use one device per person [19]. According to Table 24, desktop PCs accounted for more than half of all school levels.

TABLE XXIV
PERCENTAGE OF DIGITAL DEVICES IN SCHOOLS (%) (ADAPTED FROM THE KOREA EDUCATION AND RESEARCH INSTITUTE SERVICE [19]).

| **School Level** | **Desktop PC** | **Laptop** | **Smart Pad** |
|---|---|---|---|
| Elementary | 67.9 | 4.8 | 27.3 |
| Middle | 56.4 | 23.6 | 20.0 |
| High | 66.5 | 24.8 | 8.7 |

The rate of aged digital devices per school levels is shown in Table 25. When looking at school devices by year, 34.56% of devices have less than two years of age, 37.77% of devices have two to four years of age, and 27.67% of devices have more than five years of age. Devices over five years old are considered to be aged, so about 30 percent of the devices owned by the entire school level are aged [19]. In addition, devices between 2- and 4-years account for the largest proportion of school devices, so continuous device management is necessary in preparation for aging. When looking at the ratio of aging devices by school, it can be seen that the higher the school level, the higher the ratio of aging devices.

TABLE XXV
PERCENTAGE OF DIGITAL DEVICES IN SCHOOLS (%) (ADAPTED FROM THE KOREA EDUCATION AND RESEARCH INSTITUTE SERVICE [19]).

| **Year(s)** | **Elementary School** | **Middle School** | **High School** | **All Levels** |
|---|---|---|---|---|
| <2 | 40.60 | 30.59 | 28.58 | 34.56 |
| 2–4 | 35.15 | 40.49 | 39.66 | 37.77 |
| >5 | 24.25 | 28.92 | 31.76 | 27.67 |

∉*Wireless Internet Network:* It is necessary to install a wireless internet network in classes using portable devices such as smart pads. In 2021, wireless access points (APs) were installed in an average of 3.8 classrooms in one school. However, according to a survey, 2.4 APs were installed in each school with the least AP installed, while 46 were installed in each school with the most AP installed [29]. This indicates a significant difference in wireless AP facilities between regions. This could increase the gap in the educational environment between regions.

### *H. Discussion*

In this paper, we systematically analyzed the data of informatics and AI education in Korea using the DM. Based on the results until G in Section 3, this section further addresses discussions of how to activate informatics and AI education in Korea.

#### *1) The Status and Problems of Informatics and AI Education in Korea*

∉ *The Demand for a Systematic, Coherent Curriculum*: The informatics curriculum of elementary schools in Korea was operated as part of the "practical arts" subject [30], while informatics subjects were independent in middle and high schools. As a result, informatics education in elementary schools has a different content system from that in middle and high schools. Thus, the absence of a systematic and coherent curriculum emerged. There is no accorded goal, capacity, and content system of the curriculum through all school levels [10], [28]. This means that informatics education is difficult to implement in schools [31] systematically.

∉ *Securing Instructional Time*: Even if the curriculum is well prepared, it is challenging to implement it unless the instructional time is not secured. Currently, the standard hours given to informatics are 17 hours in elementary schools and 34 hours in middle schools, and high schools do not have a fixed compulsory instructional time. Students mentioned insufficient class time the most as a reason for dissatisfaction with informatics education, and teachers also complained of difficulties in operating the curriculum within insufficient class time. Parents also felt the lack of SW and AI education provided by public education and tried to supplement it through private education [31]. Therefore, it is necessary to expand informatics and AI instructional time more than now to increase stakeholders' satisfaction and make teachers teach students effectively.

∉ *Difficulty in Securing Qualified Teachers*: The demand for informatics-computer teachers has increased because the informatics subject was designated as a compulsory course in middle schools in the 2015 revised curriculum. On the contrary, the number of *CSE* departments and graduates has decreased. The gap between supply and demand for teachers who teach informatics subjects causes two problems. The first problem is the "a teacher teaching multi schools", in which a teacher teaches several schools in a week due to the lack of the number of teachers [19]. This makes it difficult for a teacher to prepare a student-customized education and causes the quality of informatics classes to fall because of the workload. The second problem is that the government and local governments are taking informatics classes to teachers who have majored in similar subjects (i.e., science, technology) or who have obtained informatics-computer teacher certification through special six-month training to supplement the gap [10]. As a result, only 70% of teachers who teach informatics classes have majored in informatics-computer education, and the rest of the classes were operated by teachers who have not majored in CS education. In the case of elementary teachers, some educational colleges did not even open "Elementary Computer Subject" [26], so there was no opportunity to develop the SW education capacity of pre-service teachers. In addition, there was only one question in the "Teacher Qualifications Act and Recruitment Exam" until 2021 [32], which shows that there is not enough opportunity to evaluate the development of SW education capacity of pre-teachers in elementary schools.

∉ *Lack of Technical Infrastructure*: The current technical infrastructure is as follows: there is one lab per school. Five students have only one digital device on *average*. This means that there are not enough digital devices for students and room for class, so informatics classes are likely to be conditional on the lab [19]. This means that students can use the lab only at the assigned time according to the timetable of the lab. Furthermore, if labs are occupied because of a school event or other circumstances, it is hard to have the informatics class. Furthermore, there were still desktop PCs, the most among digital devices in school, and most of the labs were composed of desktop PCs, which were not movable, making it difficult to perform various types of activities [19], [33].

*2) Discussions for the Improvement of Informatics and AI Education in Korea*

∉ *Securing Systematic and Coherent Curriculum at All School Levels*: A systematic curriculum that runs through all levels is necessary to educate informatics efficiently. To improve the current curriculum, it is possible to discuss ways to educate informatics subjects independently within the elementary school system [21]. If there are informatics subjects independent in elementary schools, it is possible to prepare curriculums that include coherent educational goals, competencies, and content systems at the school level [30]. As part of efforts to build a systematic curriculum related to AI education, there is the "Content Standards for AI Education in Elementary and Secondary Schools" developed by the KOFAC. That has the same content systems for each school level. Therefore, informatics and AI curriculums to be informed in the 2022 revised curriculum should be organized coherently and systematically at all levels of school.

∉ *Extending Instructional Time*: It is necessary to extend informatics instructional time to implement a well-*prepared* curriculum and provide efficient education [30]. Fortunately, the Ministry of Education announced that it would expand the time of informatics subjects in the 2022 revised national curriculum [34]. It is hardly possible to significantly increase educational time at once within a fixed school education period, and therefore, such efforts to gradually increase time seem very positive.

∉ *The Need to Assign Informatics-Computer Teachers More and Verify the Teachers' Teaching Competency*: Demand for informatics classes will increase more because of the implementation of the "high school credit system" of the 2022 revised curriculum [34]; even if a small number of students demand, the class can be opened. To fill the gap between the demand and supply of teachers, it is crucial to recruit and secure informatics teachers more [10], [32]. Simultaneously, it is necessary to verify whether teachers teach informatics classes effectively [26]. It is necessary to conduct a post-test on whether teachers effectively teach informatics and AI to students in the field.

∉ *Establishment and Management of Technical Infrastructure*: It is necessary to overcome the limitations of the fixed type of lab and the low supply rate per person. First of all, it is necessary to secure more room or mobile digital devices, such as smart pads, that students can freely use regardless of space [19], [32]. It is also needed to manage aged devices through regular maintenance [12]. The government and local governments implement policies to secure a budget and have a "one-person 1 device." In addition, to improve the limitation of the fixed type of lab, the Ministry of Education announced in 2020 that a project would be carried out to build a "future-type education space" [2] that promotes flexible convergent thinking activities and enables various types of classes [29]. Starting with this project, various methods of deploying technical infrastructure have been tried in experimental schools [29].

## IV. Conclusion

This study systematically analyzed and presented the state of informatics and AI education in Korea since 2015. Collecting, coding, and analyzing documents according to the DM presents the results regarding the educational system, sociocultural factors, policies, teachers, curriculum, extra curriculum activities, and media. Through the results of each part, discussions were suggested on the curriculum, education time, teacher training, and technical infrastructure for the improvement of Korean informatics and AI education.

The educational system and curriculum are established and revised according to the government. Due to the 2015 revised curriculum, informatics education turned into compulsory education for elementary and middle schools; however, the subjects related to informatics in high schools are still included in elective subjects. Informatics education is not a subject of the CSAT, so it is unlikely to be selected among elective subjects. Thus, informatics subjects in high schools need to be compulsive subjects, such as elementary and middle schools, for the linkage of education. In addition, informatics education in elementary schools is not an independent subject but one of the content areas in the "practical arts" subject, unlike in middle and high schools. Due to the discrepancy between elementary and middle, and high schools, educational goals and content systems are not accorded with each other. For coherent and systematic informatics education, further research was required to build informatics curriculums coherently at all school levels. AI education emerged in 2019, and AI-related subjects began operating in high schools in 2021. However, there are no AI curricula and subjects organized in the national curriculum in elementary and middle schools. With the development of a new curriculum, it is necessary to prepare a curriculum suitable for the school level in the future.

According to the results of sociocultural factors, the more direct and indirect experiences related to AI students have, the more positive AI attitudes they have. Due to the experience difference, attitudes toward AI significantly differed depending on age and gender. Compensating for the experience gap depending on age and gender, various experience opportunities should be provided through follow-up studies.

The public opinions of students, teachers, and parents regarding informatics and AI education have something in common. Most were satisfied with informatics and AI education, except for education time. Because of the lack of education time, parents even answered that they made their children participate in the private class. They also agreed that AI education is essential for students' future lives and jobs. One of the demands of stakeholders is to extend the education time for informatics and AI education. A platform for implementing AI education is also one of them. These should be reflected in informatics and AI education in the 2022 revised curriculum.

The Korean government made informatics education mandatory in elementary and middle schools in the 2015 revised curriculum to support it. After that, it built technical infrastructure, nurtured human resources, and created and promoted an educational culture based on the "basic plan" in 2016. In 2019, the government analyzed the performance and limitations of the plan and announced follow-up policies. "Informatics Master Plan" has been implemented through various policies, such as expanding education time and establishing a coherent curriculum to organize informatics education at all school levels. "AI National Strategy" promoted various national policies for AI education. Financial support was provided to establish AI-related subjects, secure teacher qualities, and develop the content and environment. Currently, follow-up policies are being implemented to introduce AI education content at all school levels, including kindergartens, by 2025.

As a result of analyzing teacher training and training courses, the university of education and the college of education should designate CS-related subjects as mandatory courses in the curriculum to train pre-teachers. Those who graduated from the Department of CS Education obtain informatics-computer teacher certifications, and about two hundred students graduate every year. However, as the demand for informatics and AI education has increased in schools, the number of graduates has decreased. Due to that, many teachers should teach the classes in 2–3 schools a week. It causes a serious workload on teachers and leads to a decline in the quality of education. In addition, to compensate for the lack of teachers, some local governments make teachers without certificates teach informatics subjects after short training courses. It also may cause the low quality of education. To improve the quality of informatics and AI education, it is necessary to secure more teachers and verify the informatics class capabilities of teachers.

The government encourages SW and AI gifted students to be trained in extracurricular activities. It provides advanced courses to train them in activities outside the curriculum and holds contests such as the Informatics Olympiad and AI Youth Challenge. In addition, SW and AI festivals provide people with opportunities to experience SW and AI.

There are various types of informatics textbooks at all school levels. In the case of elementary schools, contents were presented as part of the "practical arts" textbooks. Regarding AI textbooks, various types of "AI basics" and "AI mathematics" textbooks in high schools exist according to the national curriculum. In addition, six textbooks verified by each local government expanded the scope of each school to select various subjects. There is no AI subject in elementary and middle schools' national curriculum. Fortunately, educational textbooks reflecting the content system produced by the KOFAC are prepared at the school level to fill the education gap.

Technical infrastructures such as digital devices, LMS systems, and platforms were developed to distribute and operate online classes in Korea efficiently. Various educational platforms developed in Korea are useful for informatics and AI education practice. However, the number of digital devices with guaranteed performance and labs is still insufficient for informatics and AI education. Financial support for the establishment and management of devices should be secured, and research on the deployment of devices in labs is needed to implement various learning methods in labs.

As the demand for informatics and AI education in public education has been growing, they have been implemented for more than seven years. There are still opinions that have not been agreed upon on concrete plans enough. Before developing a new curriculum, it's an appropriate time to discuss what is a more advanced and improved way for informatics and AI education. Reflecting on the past, it is needed to discuss how to design informatics and AI education considering the suggestions in this paper.

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