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SOFTWARE EDUCATION IN SOUTH KOREA FOR CULTIVATING COMPUTATIONAL THINKING: OPPORTUNITIES AND CHALLENGES

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INTRODUCTION

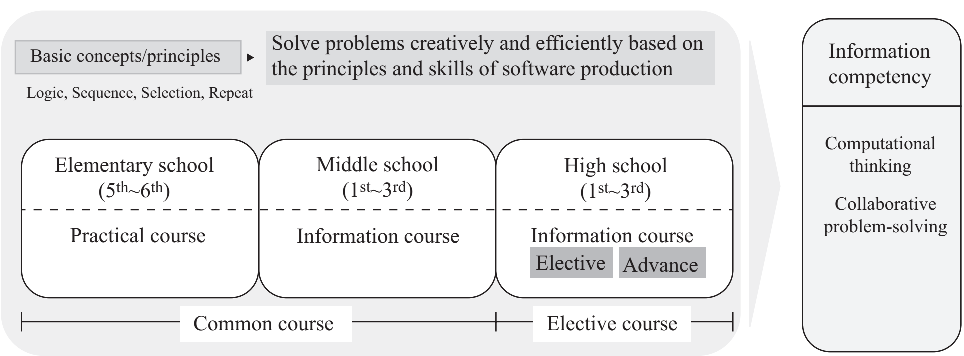
In the intelligent information society brought by the fourth Industrial Revolution, software-based innovations have become the center of value creations, enabling the design of autonomous physical-digital spaces and intelligent systems that change the way we live, learn, and work. Accordingly, several countries have been emphasizing the importance of equipping the future workforce with necessary computational skills, creativity, and logical thinking skills (Hsu, Chang, and Hung 2018). As a strategic policy move under the title of "software education"[1] (SW education hereinafter), the South Korean government has mandated SW education in elementary and middle schools. SW education, which is defined as "the education of the ways of thinking that enable students to express creative ideas through software" (Ministry of Education in South Korea 2015), was introduced in 2014 as part of the policy strategy to support a software-centered society. The educational intention of this policy initiative is to foster the culture of learning that highlights problem-solving and computational thinking (CT) skills.

With this backdrop of the education reform, the purpose of this chapter is to discuss the current status, opportunities, and challenges of implementing software education in South Korea. From 2018, software education has been introduced and mandated in the school curricula to cultivate students' computational thinking and related competencies such as creativity and communication skills. In this chapter, we first present the current status of software education in K–12 education with a particular focus on the unique features of software education in South Korea, namely (a) the inclusion of software education in the formal curricula as a single subject, (b) the top-down policy approach, and (c) the integration with STEAM (science, technology, engineering, arts, and mathematics) education. We then discuss the difficulty of changing teachers' perceptions of viewing software education as computational thinking beyond coding skills. The chapter concludes with the discussion of both opportunities and challenges that K–12 schools in South Korea have been facing in terms of changing the culture of learning coding skills, the need for developing teacher competency in both technical and pedagogical aspects, and the emergence of the commercial market of coding education.

POLICY DIRECTIONS AND INITIATIVES

INTRODUCTION OF THE NEW CURRICULA

The national-level or school-level curriculum in SW education has been determined based on the Elementary and Secondary Education Act. As summarized in figure 8.1, elementary school students receive SW education in the practical study subject for seventeen hours per year in the fifth

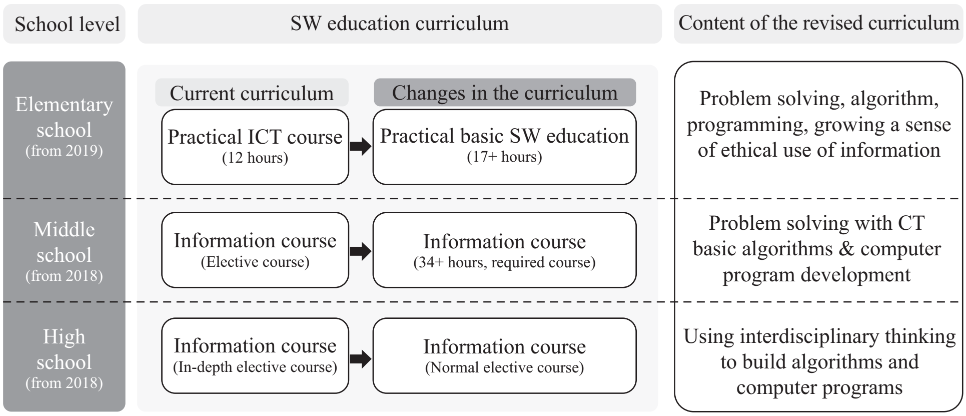


8.1 The SW education curriculum structure for each school level in South Korea.

and sixth grades. In the middle school curriculum, students receive SW education in the information subject for thirty-four hours per year.

While total curricula hours allocated for SW education are not high, the national policy on SW education has brought several changes in the existing curricula. First, the focus of SW education has changed from learning software applications to coding education. In elementary schools, while the previous curriculum centered on ICT literacy skills such as using and developing multimedia materials, the new curriculum called the 2015 National Curricula emphasizes diverse topics around computational thinking such as algorithms, information ethics, and programming. In middle schools, the previous curriculum in information science focused on teaching computer literacy skills such as creating documents and editing video clips, whereas the new curriculum includes programming skills and various topics related to computational thinking. Specifically, the components of the revised curriculum include information culture–information society–information ethics (18 percent); data and information—representation and analysis (18 percent); problem-solving and programming—abstraction, algorithms, and programming (50 percent); and the operating principles of computing systems and physical computing (14 percent). As seen in the distribution of topics, the new middle school curriculum puts a high emphasis on developing students' competency in computational thinking.

In high schools, while information science was offered as an advanced elective, most schools did not offer this subject due to the low relevance to the college entrance exam. Since the revised curriculum has changed the information subject from an advanced elective to a general elective under the science and technology subject, as of 2019, about 10 percent of high schools offer the information subject under the formal curriculum. The information subject has also been redesigned to cover various topics such as information ethics, information security, computer logic gates, the basics of C language, advanced concepts (pointers, structures, and so on), algorithms, data structures, and alignment algorithms. In particular, the new subject called advanced information science has been developed to allow students who are interested in the information science field to learn and develop advanced skills through the sustainable curriculum (see figure 8.2).



8.2 Changes in SW education in the 2015 national curricula.

Second, the introduction of SW education requires teachers to develop new competencies to provide SW education that is different from the past curriculum. While middle school teachers have advanced content knowledge in SW education, elementary school teachers are trained to teach various subjects and do not have the specific content knowledge and technical skills to teach computational thinking. Recognizing the lack of elementary school teachers' competency with SW education, the Ministry of Education established the strategic plan to offer professional development programs to 30 percent of elementary school teachers by 2019. Teacher professional development programs under the SW education initiative include software capacity building training through online learning (basic and advanced), face-to-face training, group training for lead teachers, and school-organized workshops. In addition, there are several teacher study groups formed in a voluntary way.

Third, there has been considerable investment to construct learning culture and environments conducive to SW education. Since technology is both an objective and a means in SW education, it is impossible to implement SW education in schools without creating a sufficient physical and technical environment (So, Kim, and Ryoo 2020). To change the school culture along with the support of teacher professional development, the number of lead schools in SW education has increased dramatically from 160 in 2015 to 1832 in 2019. SW education lead schools receive financial support from the Ministry of Education, which can be used for purchasing teaching and learning materials and organizing SW training camps, teacher workshops, and parent seminars. Further, wireless infrastructure in schools has been improved along with the supply of smart devices and computers.

INTEGRATION WITH STEAM EDUCATION

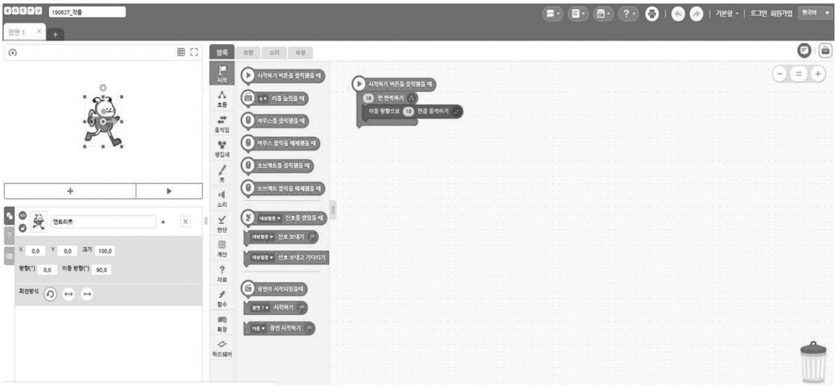
Through SW education offered in the information subject, students are exposed to a multidisciplinary education that emphasizes solving real-world problems. SW education aims to help students integrate various types of knowledge for problem-solving to go beyond learning separate subjects. For this purpose, SW education has been expanded with the integration of STEAM education and maker education. SW education can be used as part of STEAM education in which various subjects are integrated to solve challenging problems. In view of this, a new approach called computational thinking–based STEAM (CT-STEAM), which converges multiple subject knowledge to solve complex problems in the real world by utilizing various computing devices, has also been proposed (Ham, Kim, and Song 2014).

STEAM education also includes unplugged computing, which is an activity for learning about computer science concepts without the use of computers (Bell et al. 2009). Unplugged activities in the STEAM curriculum have been provided in the formal curriculum for young learners and primary school students to increase their interest in learning about computer science concepts. Unplugged computing has attracted much attention as a new method in the STEAM curriculum because the logical aspects of computer science can be taught without complex programming (Thies and Vahrenhold 2013). For upper-level elementary and middle school students who are interested in computer science, STEAM education focuses on helping them solve complex problems through programming robots and computing applications with the integration of engineering, coding, sciences, and mathematics subjects (Ngamkajornwiwat et al. 2017; Sullivan and Bers 2016). Students naturally learn about the functions and roles of robots by playing with them (Jeon et al. 2016). STEAM enrichment programs using robots can enhance students' creativity and complex problem-solving abilities (Ngamkajornwiwat et al. 2017). In South Korea, there are research studies on the STEAM enrichment programs using Littlebits in design thinking approaches (Tae 2016) and drones and hamster robots (Yoo et al. 2018).

Entry (see figure 8.3) is the most commonly used coding program in SW education in South Korea. Entry has been used in most elementary schools, whereas about 50 percent of middle and high schools use Entry. In 2013, Entry was developed by NAVER, which is the most popular web portal site in South Korea. and is a block-based coding program for users to easily learn coding skills. Entry is supported by educational materials developed with in-service teachers and experts and provides teachers with grade-level specific teaching and learning materials based on the national curriculum and lesson plans developed in collaboration with EBS (Educational Broadcasting System), which is a public broadcasting organization in South Korea. Entry also supports unplugged activities such as board games and physical computing activities (see figure 8.4).

THE EFFECTS OF SW EDUCATION

As SW education has been fully introduced in the formal curricula in schools, several research studies have reported the effects of SW education on various learning outcomes. In this section, we synthesize research



8.3 Entry interface. (image source: https://playentry.org) Copyright © Naver Connect Foundation. Some rights reserved.

8.4 Unplugged activity (left) and physical computing activity (right) in Entry. (image source: https://playentry.org) Copyright © Naver Connect Foundation. Some rights reserved.

studies that examined the effect of SW education in South Korea, according to each school level from early childhood education to high schools. For the literature search, we used the RISS service, which is the most widely used academic search database in South Korea. As shown in table 8.1, the education system in South Korea is divided into elementary, middle, and high schools, and SW education has been offered differently at each education level. As mentioned earlier, SW education has been mandated in elementary, middle, and high school as part of the formal curricula. The Nuri curriculum is commonly applied to kindergartens and daycare centers across the country but does not include specific components for SW education. With increasing interest in coding education with the emphasis on playful activities, many kindergartens have been implementing coding education programs.

First, research on SW education in early childhood education has been conducted as part of the Nuri curriculum to examine children's attitudes and perceptions about software applications. Jung and Park (2018) examined the effect of using unplugged activities for children. The comparison between the control group ($N=18$) and the experimental group ($N=20$) showed that children in the experimental group that used unplugged activities showed higher levels of creativity and problem-solving than their counterparts in the control group. In general, children understand the process of building and operating robots through playful activities. With that, recent programs attempt to integrate playful activities in SW education. For instance, Kim, Hong, and Kim (2016) developed

Table 8.1 SW education-related curricula at each school level

School level	Educational target	Related curriculum
Early childhood education	Children before primary education (aged 0–7)	Nuri curriculum
Elementary school education (6 years)	Students aged 8–13	SW education, STEAM education
Middle and high school education (3 years+3 years)	Middle school: students aged 14–16; high school: students aged 17–19	SW education, STEAM education, free semester

instructional tools with QR codes to teach CT through playful activities. To do this, they categorized children's CT into ten categories such as transformational thinking, recursive thinking, and abstract thinking and developed relevant teaching materials in language, manipulation, and rhythm areas. Some gaps in the existing research with young children's CT were also found. While the existing literature examined the impact of SW education for young learners, little is known about how children form CT in the developmental process, implying the need for shifting the research focus from outcome-oriented to process-oriented approaches.

Second, several research studies conducted in the elementary education context examined the effects of the SW education activities such as block coding programs (e.g., Scratch, Entry, and Bitbrick) and hamster robots. Such learning activities helped students develop CT-based problem-solving skills and logical thinking. For instance, Lee, Park, and Choi (2018) conducted the SW education program with robots for eighty-eight students in the fifth grade for three months and found that students' CT, creativity, and academic interests improved significantly after participating in the program. Some studies examined the effectiveness of SW education integrated with the STEAM approach. Kim (2015) developed the 4C (creativity, communication, caring, and convergence)-STEAM education model with twenty-two curriculum activities under six themes in engineering and technology. The study reported that the group who participated in the STEAM curriculum was more satisfied with the learning experience and showed higher logical thinking ability than the control group.

In addition, some studies examined the different levels of CT according to learner characteristics. For example, Park et al. (2017) investigated 4,363 students in the fifth and sixth grades in forty-five SW leading schools to identify the main factors affecting students' CT and attitude toward SW education. Their study examined three levels of student characteristics factors: level 1—within-student factors (i.e., CT and attitude toward SW education); level 2—between-student factors (i.e., gender, computer ownership, Internet usage time, prior SW education experiences, participation in SW competitions, awareness of SW education, satisfaction with SW education, time on SW training, and participation in SW education through in-school and after-school programs); and level 3—school-level factors (i.e., city size and the number of students). The study found that the period of SW education and participation in the SW-related after-school programs at level 2 had the greatest influence on students' CT. Other level 2 variables such as the awareness of SW education and satisfaction with SW education showed significant influences on students' attitudes toward SW education. As another related study, Noh and Lee (2017) examined the SW education program with robotics for 155 students in the fifth and sixth grades and analyzed their level of CT and creativity according to prior knowledge and gender. They found that prior knowledge related to SW education played a significant role in CT and suggested the need to support programs that CT could be improved through various experiences.

Third, research conducted in the middle and high school context is relatively scarce compared to the number of studies done in the elementary school context, and most existing studies focus on identifying factors affecting students' CT. For instance, Lee and Ko (2018) examined the level of CT among eighty-three students in middle school who received SW education in the information subject for six months. They found that the subfactors of CT (i.e., critical thinking, creativity, algorithmic thinking, and problem-solving ability) increased significantly, and the students acquired CT-related concepts and perspectives through the SW education activities. Hwang, Mun, and Park (2016) examined the impact of unplugged activities in the SW education club for twenty-three high school students who used education programming language (EPL) software and physical computing tools. The study found that the students showed improved programming skills, CT, and confidence in problem-solving through computing after participating in the club activities. Additionally, some studies examined differences in student perceptions about CT and SW according to individual characteristics. Lee, Jo, and Kim (2019) examined 422 middle school students' awareness about SW (i.e., SW environment, SW education awareness, and SW career interest) according to their gender. They found that the male students were more interested in learning about SW than the female students. In addition, while 76 percent of the male students were exposed to SW education, only 54 percent of the female students had SW-related prior experiences. Overall, they suggested the need to increase female students' confidence and interest toward SW education.

In summary, our review reveals that most studies in the area of SW education in the South Korean context have been conducted with students in elementary schools and have attempted to identify factors related to the effects of SW education. Given the increase of research on young children, we also confirmed the expansion of SW education across various school levels. Kindergarten and elementary school students tended to use unplugging activities and block coding, whereas middle and high school students were participating in higher-level SW classes with Python and C programing language. For the sustainability of SW education, it needs to be integrated with other subject studies, as seen in the increased interest in integrating SW education with STEAM approaches. In addition, we also suggest the need for longitudinal studies of cohorts at each school level to examine the long-term outcomes of SW education.

BARRIERS TO SW EDUCATION

While teachers play an important role in the spread and adoption of SW education in South Korea, they also experience some barriers in implementing SW education because of the difficulty in applying new teaching methods and technologies. Teachers need to acquire certain content knowledge in computer science to competently teach SW education in the classroom (Saeli et al. 2011). Teachers also need to design challenging tasks and provide pedagogical support to help students solve computational problems that are connected to authentic contexts (Krauss and Prottsman 2017).

Ertmer (1999; 2005) suggests that teachers face both external (first-order) and internal (second-order) barriers when integrating new technologies into teaching and learning practices. First-order barriers refer to obstacles that are external to teachers and are often described as a lack of resources such as insufficient equipment, time, financial, and administrative support. These types of barriers can be overcome incrementally at an institutional level once adequate resources are provided. On the other hand, second-order barriers are intrinsic to teachers such as epistemological beliefs and attitudes. Ertmer (1999; 2005) argues that second-order barriers are more difficult to change or remove as they are deeply ingrained, intangible, and personal factors. Teachers are reluctant to use new technology when they perceive a high degree of uncertainty and risk that new technology brings along (Le Fevre 2014). To overcome second-order barriers, it is necessary to change teachers' belief systems by providing opportunities to experience the potential of new pedagogical methods (Blackwell et al. 2013; Donnelly, McGarr, and O'Reilly 2011). In this section, we discuss various barriers that South Korean teachers have experienced in the implementation of SW education in terms of first-order and second-order barriers.

Some research studies have reported environmental and structural factors as first-order barriers. Kim and Jun (2019) conducted a study with 181 elementary school teachers to identify their perceptions about the SW education policy. The IPA (Importance-Performance Analysis) revealed that teachers perceived policy support and skill enhancement through professional development as important factors. There was a great demand for policy support for improving school environments, such as securing digital devices, wireless networks, and budget support. Teachers also perceived high importance about learning instructional strategies that can be applied to SW lessons, such as analyzing learners, accommodating learners' diverse ability levels, and utilization ICT tools. The study by Ryoo, So, and Kim (2019) demonstrates how first-order barriers can affect second-order barriers such as teachers' beliefs. Their study classified four types of teachers, namely the innovative teacher, the serious teacher, the insecure teacher, and the confused teacher, based on knowledge/skill levels (surplus versus shortage) and pedagogical beliefs (positive versus negative). Teachers commonly pointed out the lack of resources in SW classes as one of the serious factors affecting their adoption and implementation of SW education. In particular, the serious teacher (surplus of skills, low pedagogical belief), despite having sufficient knowledge and skills, experienced difficulty in operating SW education due to the insufficient financial support and lack of school infrastructure. On the other hand, the insecure teacher (shortage of skills, high pedagogical belief) did not have enough knowledge and skills to implement SW education and expressed concerns about how to implement SW lessons in class. Despite their concern about the lack of knowledge and skills, an encouraging finding was that the insecure teacher type tends to believe that SW education can provide students with opportunities to develop necessary competence demanded in the future society. The Ministry of Education in South Korea has recognized such problems related to school environments that are not conducive to SW education and has established a strategic plan to provide wireless Internet infrastructure to elementary schools by 2020 and middle schools by 2021 and to replace outdated hardware applications and devices.

Another problem related to the first-order barriers is that teachers did not receive enough training about SW education during their teacher education programs. Since the SW curriculum is mandatory and requires curriculum hours, teachers need to develop teaching competence to design, implement, and evaluate the mandatory curriculum implementation. To overcome this barrier related to teacher training, the Ministry of Education and the Ministry of Science and Technology and Information and Communication in South Korea have provided training programs to 6,800 teachers (30 percent of all elementary school teachers) and about 1,800 information subject teachers in middle schools. In particular, one of the national tasks is that the core teacher training in SW education will be conducted until 2021, with the aim to cultivate ten thousand core teachers leading SW education (Ministry of Education in South Korea 2018). Teachers in elementary schools will receive training courses about understanding CT, unplugged activities, acquisition of EPL, and SW education with robots. Teachers in middle and high schools will receive training courses on more advanced topics such as physical computing and text-based programming (Korea Education & Research Information Service 2017a, 2017b).

In addition, there are attempts to hire assistant teachers for in-service teachers who do not have enough knowledge and skills of programming and have great difficulty in the teaching process. The use of assistant teachers in South Korea has been already implemented in English education and inclusive education for children with disabilities. Noh (2018) examined the impact of having assistant teachers in SW classes. Both the experimental group and the control group had the same teacher and class contents, but the assistant teacher in the experimental group was responsible for observing students, answering questions, and providing necessary information in the debugging process. The study found that students in the experimental group performed significantly better than their counterparts in the control group. Besides human support, teachers need guidelines and educational materials for SW education. Hence, the Ministry of Education, the Ministry of Science and Technology, and various institutions such as KERIS and EBS have collaborated to develop teaching and learning materials for SW education.

Next, previous studies have identified second-order barriers such as teachers' perceptions and attitudes about SW education. Lee, Chung, and Ko (2018) identified factors that influenced elementary school teachers' intention to implement SW education based on the Technology Acceptance Model (TAM), which explains individuals' intention to use new technology through two factors, namely the perceived ease of use and the perceived usefulness (Davis 1989). Lee et al. (2018) found that teachers' attitudes about SW education completely mediate their perceived ease of use, perceived usefulness, personal innovation, and intention to implement SW education. In addition, the perceived ease of use had a direct effect on the perceived usefulness and an indirect effect on the intention to implement SW education.

Lee and Lee (2019) examined the variables that predict teachers' beliefs about SW education. Training experience and time related to professional development about SW education were predictive variables. In another study, they examined the impact of PD programs about backward design on teachers' beliefs. The training program provided the teachers with the opportunity for in-depth experiences designing lesson plans based on the backward design approach. It found that the process of professional development was improved by teachers' beliefs. In summary, a teacher's attitude about SW education was a major factor in predicting their intention to implement SW education, implying that teachers' positive attitudes influence not only the development of teacher expertise in SW education but also actual classroom implementations.

However, it is important to note that acquiring the necessary knowledge alone does not help teachers develop sufficient professional competency. From the perspective of technological pedagogical content knowledge (TPCK) proposed by Koehler and Mishra (2009), So and Kim (2009) argue that even when teachers have strong beliefs about technology integration (espoused TPCK), they tend to experience difficulty designing technology-integrated lessons in practices (in-use TPCK). This problem arises when teachers have not formed tight connections among pedagogy, content, and technology. One way to overcome this conflict between espoused TPCK and in-use TPCK is to help teachers acquire explicit knowledge and change beliefs at the same time (Kane, Sandretto, and Heath 2002). Belief is a source of change for teachers, and a belief system is formed over time through embodied experiences (Hansen and Rosenlund 2018). Hence, teachers need to develop relevant knowledge, skills, and beliefs to innovate teaching and learning practices with new technologies. For instance, Angeli et al. (2016) propose the concept of TPCK for computational thinking ($TPCK_{CT}$) that refers to teacher knowledge in terms of identifying a range of creative and authentic projects for CT, identifying a range of technologies to support CT in each project, and integrating content knowledge and pedagogical knowledge to make the overall CT experiences comprehensive to all learners. Angeli et al. (2016) also reported that the learning-by-design approach where teachers are engaged in designing models of different problem situations and constructing computer programs could improve $TPCK_{CT}$. A similar approach emphasizing teachers as designers can be adopted in the teacher preparation program in South Korea to equip future teachers to better deal with the complexity of designing and implementing the SW education curriculum and to help their students develop adequate CT.

DISCUSSION AND CONCLUSION

The increasing interest toward CT in K–12 education is a global phenomenon, and many countries have initiatives to promote CT in formal education. South Korea is not an exception in this global CT movement. The SW education initiative in K–12 schools in South Korea has been positioned as the major education reform movement toward cultivating students' computational skills and creative problem-solving skills demanded in a creative economy. In tracing the historical development and spread of CT, Tedre and Denning (2016) argue that translating ideas underlying CT into K–12 education is a major challenging as most teachers lack computer science knowledge. Further, they list several threats to CT initiatives, namely the lack of ambition, dogmatism, knowing versus doing, exaggerated claims, narrow views of computing, overemphasis on the formulation, and lost sight of computational models. This chapter also reveals that cultivating CT in South Korean K–12 schools under the overarching SW education policy has faced several challenges despite the macro-level support from the government. Based on the review of the current status and research on SW education, we have drawn the following four features about the early stage of SW education in South Korea.

First, SW education in South Korea has been introduced based on the national curriculum. Although there were some difficulties in the initial process of its introduction, the awareness of the necessity of introducing SW education has been increasing gradually. Teacher changes have been observed in teacher learning communities where they attempt to build necessary knowledge and skills through bottom-up initiatives. For example, the Association of Teachers for Computing, which is the largest teacher-initiated community for SW education in South Korea, has various channels such as social media and workshops to communicate with teachers and has made various teaching and learning materials available for teachers. When there is a mechanism to support teachers' voluntary and bottom-up movements such as this teacher community, SW education can be successfully promoted and implemented in schools.

Second, there have been continuous efforts for improving teachers' SW teaching competency through the provision of various professional development programs. There are high demands on offering differentiated training programs according to individual teacher's prior knowledge, gender, teaching experiences, and training experiences (Ryoo et al. 2019). As of the 2019 statistics, the average age of teachers in South Korea is about 40.4 years old for elementary schools, 43 years old in middle schools, and 43.3 years old in high schools (Korea Educational Development Institute

2019). Since teachers' age has been reported as one of the important variables in technology integration, the design of teacher training programs for SW education needs to consider teachers' life cycles (Kale and Goh 2014).

Third, regional differences in implementing SW education have been reported, indicating the educational disparity. In South Korea, as technology infrastructure has been built around urban areas, less manpower and equipment have been provided in rural areas. The proportion of information science teachers who could teach SW education was 49.9 percent in 2019. Itinerant teachers who travel to teach at various schools in the region are used for solving the problem of lack of qualified SW education teachers in rural areas. Further, standardized lesson plans and necessary materials have been developed to help teachers in rural areas who have fewer technical skills implement lessons in SW education.

Lastly, the emphasis on SW education in the formal curriculum has led to the expansion of the private education market for coding classes, which has been growing dramatically without relevant regulations. The private education market for coding education has appeared in various formats such as coding schools, coding cafés, and after-school programs. It has been reported that about 84.5 percent of students received coding education through private education institutions (Hur 2019). Such a large private education market is a serious problem as it may create another education gap between those who can afford the cost of private education and those who cannot afford it. Since private education institutions are centered in urban areas, this phenomenon may become another source of regional differences in the quality of education. Further, since private tutoring focuses on producing visible results quickly, it can obscure the essence of SW education, which is to enhance CT skills. However, considering that private tutoring has the flexibility to respond to changes in technology faster than formal schooling, it would be undesirable to regulate private tutoring. Ultimately, public education and private education should compensate each other to spread SW education through collaborative strategies.

In conclusion, we suggest that the major challenges faced in SW education by K–12 schools in South Korea include changing the culture of teaching and learning coding skills, the need for developing teacher competency in both technical and pedagogical aspects, and the tensions between policy imperatives and school practices. It is expected that this chapter presents information about the current status of SW education in South Korea in terms of both opportunities and challenges, and such information can be used to inform countries with a similar trajectory toward cultivating students' CT through the formal curriculum.

NOTE

1. The term "software education" is the English version of the official naming in Korean "소프트웨어 [software] 교육 [education]" of the concerned policy initiative in Korea.

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