Original Article

Analysis of SW Education Program of SW Leading Elementary, Middle and High schools

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Abstract — *SW education is to cultivate talented people who logically solve problems through computational thinking, and software education has been operated as a regular subject in an elementary, middle, and high school education environment in Korea since 2018. In this study, SW education programs, SW education tools, and activities for each school level were described through the analysis of 107 SW leading school operation programs in the Jeonbuk region in 2020. In addition, improvement measures were derived for the effectiveness of SW education and the establishment of SW education through the operation of SW leading schools. This study can understand the necessity of operating SW education for each elementary, middle, and high school level and contribute to the policy improvement for establishing SW education.*

Keywords — *SW education in elementary, middle and high school, SW leading school, AI education, SW education language, physical programming, robot programming.*

I. INTRODUCTION

At the centre of the paradigm shift to the 4th industrial revolution is the SW revolution. In particular, the interest in SW-related industries is increasing as the role of SW becomes more important, especially in major technologies of the 4th industrial revolution such as robots, artificial intelligence, and IoT [1]. State-of-the-art SW technology is causing great changes in all industrial fields and society under the name of the 4th industrial revolution, and SW education that delivers SW competency is becoming a necessity, not an option, for citizens who will live in the era of hyper-connectivity and hyper-convergence. SW education aims to cultivate convergent and creative talents to strengthen their capabilities to solve problems through computational thinking in various academic and industrial fields.

Computer education is operated as a compulsory curriculum in many countries, including the United States,

the United Kingdom, Japan, China, Israel, and Finland [2,3,4,5,6], and SW-centered "information" courses have become essential in Korea through the 2015 revised curriculum. After SW education for middle schools in 2018 and elementary schools in 2019 became, mandatory, elementary and middle schools are trying to vitalize SW education through regular subjects, after-school activities, and club activities [7].

Table 1. SW Leading School Operation Status (National)

Year	The school (Number)				
	ES	**MS**	**HS**	**Special**	**Total**
2015	53	90	17	0	160
2016	434	277	121	0	832
2017	617	355	184	0	1,156
2018	922	442	233	0	1,597
2019	1,082	462	279	11	1,834
2020	1,197	494	303	17	2,011
Total	4,305	2,120	1,137	28	7,590

Abbreviation: ES stands for elementary school, MS stands for middle school, and HS stands for high school, respectively.

The Ministry of Science and ICT and the Ministry of Education have been operating SW leading schools for elementary, middle and high schools to revitalize school-oriented software since 2015. They are making efforts to lay the foundation for artificial intelligence education in elementary and secondary schools through the operation of an artificial intelligence education pilot school from 2020. SW leading schools were operated to prepare for compulsory SW education, which started in stages in 2018. As shown in Table 1, 160 SW leading schools were selected for elementary, middle, and high schools in 2015. Every year, the number of SW leading schools, including continuously operating schools and newly selected schools, continued to increase, and 2,011 SW leading schools, including elementary, middle, and high special schools, were selected

in 2020. In particular, as the need for AI education increased, SW leading schools and AI leading schools were separately selected and operated from 2020, and 247 out of 2020 SW leading schools were operated as AI leading schools [8,9,10].

By utilizing the activity analysis of SW leading schools in elementary, middle and high schools, this study aims to find out how to link education through SW education status, regular subjects and creative experience activities, free semesters, after-school activities, and other activities. In addition, the effectiveness of SW education through SW leading schools and improvement plans for establishing SW education in school sites are to be investigated. For this purpose, 107 reports of elementary, middle and high school SW leading schools in Jeonbuk in 2020 were analyzed in this study, and the types of SW education programs for each school, operation results, SW teaching materials and effectiveness, and preparation status at school sites were analyzed.

Chapter 2 of this paper examines prior studies on SW curriculum, SW education effectiveness, and SW leading school program analysis, Chapter 3 analyzes programs operated by SW leading schools in Jeonbuk in 2020, Chapter 4 analyzes the effectiveness of SW leading school operation and improvement measures for SW education establishment, and Chapter 5 describes conclusions.

II. RELATED STUDIES

Artificial intelligence and convergence areas with data science, artificial intelligence, and robotics as sub-areas were newly included In the next-generation SW education standard model development research [11]. Artificial intelligence curriculum, guidelines, and courses for elementary and middle school students at home and abroad were comprehensively compared and analyzed in the AI curriculum analysis study [12].

In the exploratory study of the artificial intelligence education content system [13], the five areas of "understanding artificial intelligence, artificial intelligence and data, artificial intelligence algorithm, application of artificial intelligence, artificial intelligence and social impact" were organized equally in the compulsory elementary and middle schools, presenting continuous artificial intelligence education content system.

In the meantime, SW/AI-related curriculum research for elementary school [14,15,16], SW curriculum research for middle school [17,18], and SW curriculum research for SW-centered universities [19] have been conducted. Various studies [10, 20, 21], including surveys on the effectiveness of leading SW schools, comparison with general schools, and perceptions on SW education, were conducted for SW leading schools. Studies related to the effectiveness of SW education and robot utilization education [22,23] and a study on Nobel engineering education [24] linking SW education and humanities courses were also conducted. SW education activities and analysis of various teaching materials used in educational activities were also presented in the study on the effectiveness of SW teaching materials and the reinforcement of SW education competency of pre-primary school teachers [25,26].

III. ANALYSIS OF SW LEADING SCHOOL OPERATION PROGRAM

SW leading schools in elementary, middle, and high schools, which have been in operation since 2015, have conducted regular curriculum classes, creative experience activities (voluntary service career), free semesters, after-school schools, pilot classes, parent briefing sessions, student experience programs, and SW competitions. The software education leading school operated various software education programs in subjects (practical arts in elementary school, information in middle school), creative experience activities, free semesters, or student clubs, and played a role in revitalizing software education through special lectures and class disclosure for teachers and parents.

The Jeollabuk-do Office of Education selected and operated 73 elementary schools, 20 middle schools, and 14 high schools as leading SW schools in 2020. In this chapter, the current status on the SW curriculum of the leading school, SW education program and creative experience activities, and the programming language and teaching tools used was analyzed, focusing on the results of the operation of the leading SW schools in the Jeollabuk-do in 2020.

A. Analysis of F SW Leading School Operation Program

According to the 2015 revised curriculum, SW education has been mandatory as follows. It has been providing more than 17 hours of "practical arts" subjects for 5th to 6th graders in elementary schools since 2019 and more than 34 hours of "information" subjects in middle schools since 2018. Table 2 shows the operating program status of SW leading schools in elementary, middle and high schools. The education program can be divided into regular subjects, creative experience activities, free semester (middle school), after-school activities, and other activities.

An analysis of the SW program in the regular curriculum of elementary, middle and high schools is as follows.
- In elementary school, classes are conducted in practical subjects and consist of SW convergence classes in the order of science, Korean, morality, social studies, and so on.
- In elementary school, regular classes consist of unplugged, entry, problem solving using scratch, creative design, and algorithm classes, and basic SW education is conducted.
- In the secondary course, classes are conducted in information subjects, and SW convergence classes are partially composed of information science and other subjects.
- Regular classes in the secondary course consist of information and communication ethics, algorithms, programming, physical computing, and maker classes and are conducted as problem-solving classes for real-life application along with SW education.

Table 2. Analysis of SW Education Program for Elementary, Middle and High School

Division		Contents(School #)
ES (73)	Regular subject	Practical Arts(73), Science(14), Korean(9), Moral(7), Art(7), Social Studies(6), Integrated Subject(4), Mathematics(3), Music(2), Physical Education(1) , Fall(1), Winter(1)
	Creative Experience	SW Club(35), SW Education(31), SW Experience Learning(11), Robot Education(10), SW Events (9), Career Education(6), Unplugged(5), SW Observation Activities(1), Nobel Engineering(1)
	After-School Activity	Student Club(30), SW Education(29), SW Camp(1)
	Other Subjects	SW Education (45), SW Teacher Training (45), SW Parent Information and Training(23), SW Camp(21), Student Club (15), Class Opening(15), Class Consultation and Consulting(10), SW Experience(7), SW Day(7), SW Competition(4)
MS (20)	Regular Subject	Information(20), History(1), Society(1), Science(1)
	Creative Experience	Student Club(9), SW Education(2), Algorithm Education(1), Competition(2), SW Event(1)
	Free Semester	Student Club(11), SW Camp(1), Career Education(1)
	After-School Activity	SW Education(11), Student Club(2)
	Other Subjects	SW Education(8), Student Club(8), Open-Class(5), SW Parent Information and Training(5), SW Teacher Training(3), SW Camp(3), SW Competition(2), SW Day (1)
HS (14)	Regular Subject	Information(11), Information Science(3), Technology & Home(2), Electrical Circuit(1), Electrical Electric Facility(1), Office Administration(1), Office Management(1), Art(1)
	Creative Experience	Student Club(16), Career Education(1), SW Education(1), SW Experience Activities(1)
	After-School Activity	SW Education(10), Student Club(1)
	Other Subjects	SW Education(8), Open-Class(5), SW Teacher Training(5), SW Competition(3), SW Parent Information and Training(2), Student Club(1), SW Camp(1)

The analysis of creative experience activities, after-school activities, and other programs in elementary school is as follows.

- SW coding education, robot utilization education, and maker education are conducted focusing on SW education contents that are insufficient in regular subjects.
- Problem-solving, physical programming, IoT and AI education and experience activities are conducted after organizing student and teacher clubs.
- Through SW training and teacher council, SW professional teachers conduct the competency enhancement and class case sharing activity.
- SW competitions, hackathons, SW experience events, and Invitation of SW experts will be held through SW Camp and SW Day.
- Conducting activities to enhance understanding of SW education through parent training and briefing sessions.
- SW education, which is insufficient in regular subjects, is organized and conducted in various forms through creative experiences, after-school, free semesters (middle school), and other activities.

B. Analysis of SW and teaching aids of SW leading schools

Table 3 shows the current status of educational SW and teaching aids used for SW education in SW leading schools. The direction of operation of the education program of elementary, middle and high schools can be confirmed by examining the SW and teaching aids used.

Table 3. Analysis of SW and teaching aids for SW education of elementary, middle and high school

Division		Contents (School#)
ES	SW	Entry(39), Unplugged(35), Scratch(22), code.org(8), C(6), Minecraft(5), Autodraw(2), Machine Learning For Kids(2), Google Quickdraw(2), Python(1), Teachable Machine(1)
	Teaching Aids (more than 5 times)	Hamsterbot(34), Drone(33), Bitbrick (17), 3D Pen(15), Microbit(12), LEGO EV3(12), 3D Printer(12), Ozobot (12), LEGO Weido(11), Spike Prime(10), Neobot(10), Board Game(10), TrueTruebot(7), Kamibot (7), Turtlebot (6), Arduino(6), Robot Master(6), AI speaker(5), VR(5), AR(5)
MS	SW	Scratch(10), C(9), Entry(7), Illustration(7), code.org(5), AppMaker(3), Unplugged(3), Teaching Machine(2), Python(1), Machine Learning For Kids (1), Photoshop(1), Premiere(1), Google Quick Draw(1)
	Teaching Aids (more than 2 times)	Arduino(9), Drone(8), 3D Printer(7), 3D Pen(5), Microbit(6), Hamsterbot(5), RoboMaster(3), IoT(2), mBot(3), LEGO EV3(2)
HS	SW	C(5), Scratch(5), Entry(3), mBlock(3), Python(1), Unplugged(1), Solidworks(1)
	Teaching Aids (more than 2 times)	3D Printer(7), Arduino(5), Drone(4), Hamsterbot(2), KT Edupack(2)

When analyzing the SW used in elementary, middle, and high schools, SW and teaching tools are used in elementary courses, focusing on basic algorithms and experiential activities. In addition, in the secondary course, SW and teaching aids necessary for problem-solving, maker education, and convergence education are used as follows.

- In elementary schools, SW for board games, code.org, for entry, scratch, and unplugged activities are mainly used, and Google QuickDraw and teachable machines for AI education are partly used.
- A wide variety of physical program teaching aids such as hamster but, drone, bitbrick, 3D pen, and microbit are being used in elementary schools.
- In secondary courses, Scratch, C, Entry, Illustration, and App Maker programs are mainly used, and some programs for unplugged education or AI education are used.
- Arduino, drone, 3D printer, 3D pen, microbit, hamster but, etc., are mainly used for regular curriculum, maker education, and club activities as teaching aids for secondary courses.

IV. ANALYSIS OF THE EFFECTIVENESS OF SW LEADING SCHOOL OPERATION AND THE DIRECTION OF SW EDUCATION IMPROVEMENT

This chapter describes the analysis of the effectiveness of the operation of SW leading schools for elementary, middle and high schools and improvement plans for the establishment of SW education described in the 2020 SW Leading School Operation Results Report in Jeonbuk Region. Regarding the effectiveness of SW leading school operation, opinions were presented from 107 elementary schools, 20 middle schools, and 14 high schools. These can be divided into 7 categories as follows: 'students and teachers' SW education understanding (understanding)', 'students' interests in SW education (interest)', 'students' SW competency (SW competency)', 'expertise of SW teacher in charge (SW teacher's expertise)', 'development and operation of SW curriculum (SW curriculum)', 'infrastructure for SW education (infrastructure)', 'parents' understanding for SW education (parents' understanding level)'.

Fig. 1 shows the effectiveness of seven items in elementary, middle, and high schools. Through the operation of SW leading schools, students' SW competencies (SW coding ability, robot utilization ability, problem-solving ability, creativity, cooperative ability, etc.) were most improved. The effectiveness of SW leading schools by school level is analyzed as follows. In elementary school, the effectiveness was high in the order of SW competency (100%), understanding (35.7%), interest (35.7%), parent understanding (21.4%), infrastructure (21.4%), SW teacher expertise (14.3%), and SW curriculum (7.1%). In middle school, the effectiveness was high in the order of understanding (35%), SW competency (35%), SW curriculum (30%), interest(25%), SW teacher expertise (15%), infrastructure (15%), and parent understanding (10%). In high school, the effectiveness was high in the order of SW

competency (100%), understanding (35.7%), interest (35.7%), infrastructure (21.4%), understanding (21.4), SW teacher expertise (14.3%), and SW curriculum (7.1%).
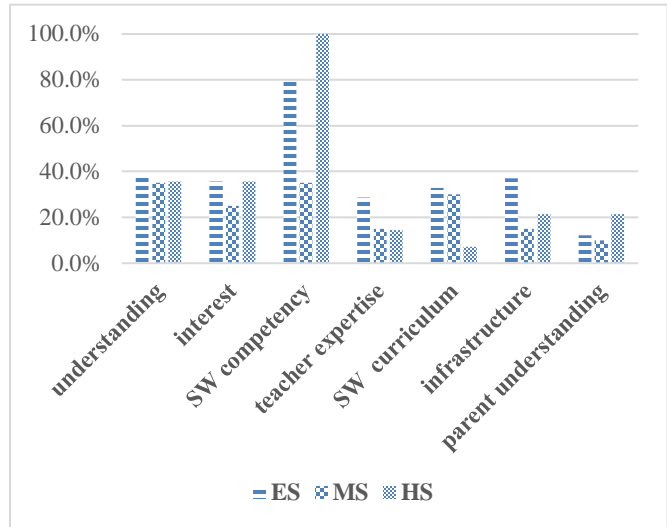

Fig. 1 Effectiveness Analysis in the Operations of SW Leading Schools

Regarding the improvement plan for SW education in elementary, middle and high schools, opinions were presented from 147 elementary schools, 33 middle schools, and 29 high schools. These opinions can be divided into five categories as follows: 'Professionalism of teachers for SW education (teacher competency), 'Infrastructure for SW education (infrastructure)', ' Development and operation of SW curriculum (curriculum), 'The number of hours of SW education (number of hours)', 'Understanding level for SW education (degree of understanding)'.

Fig. 2 shows the weights of improvement measures in 5 items for establishing SW education in elementary, middle and high schools. It can be seen that there is the highest need for improvement in the curriculum for SW education (development of SW curriculum, development of textbooks and teaching aids for curriculum operation). The improvements to SW education are analyzed by school level as follows. In elementary school, the need for improvement was highest in the order of curriculum (61.6%), teacher competency (50.7%), infrastructure (42.5%), understanding (27.4%), and a number of hours (19.2%).In middle school, the need for improvement was highest in the order of curriculum (65%), teacher competency (40%), infrastructure (25%), number of hours (25%), and understanding (10%).In high school, the need for improvement was highest in the order of teacher competency (57.1%), curriculum (50%), understanding (42.7%), infrastructure (28.6%), and the number of hours (28.6%).
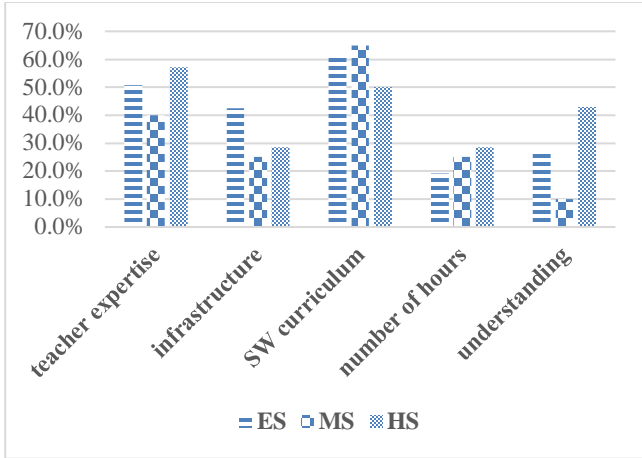
Fig. 2 Improvement Analysis in the Operation of SW Leading Schools

The opinions suggested as a way to strengthen the competency of teachers in charge of SW education are as follows:

- Expanding expertise through online and offline training for SW education and AI education
- Reinforcing the network between SW teachers and expanding teacher exchange plans through teacher club activities
- Sharing SW education methods and cases through visiting training by professional teachers with verified SW competency
-

The opinions presented as a way to improve the SW education infrastructure are as follows:

- Expanding the distribution of various devices and teaching aids (unplugged, smart pad, robot, drone, 3D printer, laptop, etc.) for SW education
- Establishment and expansion of a dedicated space (computer room, smart device room, SW experience activity space) for SW education
- Expanding the establishment of wired and wireless networks in schools
- Establishing a system that can utilize various SW teaching aids by introducing a common utilization system for SW teaching aids

The opinions suggested as a way to improve the curriculum for SW education are as follows:

- Dividing the curriculum into SW education, maker education, AI education, and STEAM education, and presenting a curriculum suitable for the course
- Presenting a convergence curriculum linked to various subjects
- Presenting SW curriculum suitable for blended learning and online and offline education
- Selecting educational materials and teaching aids for the

operation of the curriculum and presenting an appropriate educational model using educational materials and teaching aids

- Design and distribution of integrated curriculum considering the hierarchy of elementary, middle, and high school levels and grades
- Providing a way to use SW education for further education and career in connection with students' career education and activities
-

Opinions suggested as a way to improve the number of hours in SW education are as follows:

- The number of hours should be expanded since the 17th class of the elementary school and 34th class of secondary courses are insufficient for SW education and AI education.
- Expand the number of hours of convergence education that can be linked with SW education in subjects other than practical and information subjects

The opinions suggested as a way to improve the understanding of SW education are as follows:

- The development and distribution of various materials and the expansion of promotional activities to increase the necessity interest of SW education
- Proposing a plan to link career education, experience activities, major subjects, and humanities subjects through SW education
- Providing opportunities to increase the need for SW education in life through competitions and SW Day events

V. CONCLUSION

The importance of fostering talent with SW capabilities to lead the era of the 4th industrial revolution is increasing. Therefore, the importance of introducing elementary and secondary education courses to cultivate creative problem-solving skills based on computational thinking skills rather than the ability to acquire simple knowledge is urgently required. In order to establish SW education in the elementary and middle schools that started in 2018, it is also necessary to study the current status of SW education in SW leading schools and the effectiveness and improvement of SW education.

In this study, the current status of programs through SW education regular curriculum operation, creative experiential activities, after-school activities, free semesters, and program through other activities, EPL and teaching aids, and student club programs is presented by using the report of 107 leading SW schools in Jeollabuk-do in 2020.

The necessity and effectiveness of SW education through SW leading schools were confirmed as follows. First, the SW competency of students and teachers was improved through the application of the school field. Second, the development and application of infrastructure and curriculum for SW education and improvement of understanding of SW

education for parents were confirmed. Third, curriculum and textbooks, verification of teaching aids, and the number of hours in education were confirmed for SW education in elementary and secondary courses. Fifth, it was necessary to improve the SW education infrastructure and the professionalism of teachers.

This study can understand the necessity of operating SW education for each elementary, middle, and high school level and contribute to policy improvement for the establishment of SW education.

REFERENCES

[1] K. Schwab, Available: https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab, Industrial Engineering Magazine 23(2), 13-22.

[2] J. F. Sargent. The US science and engineering workforce: Recent, current, and projected employment, wages, and unemployment. 2017.

[3] e-Skills UK. Technology Insights 2012. Available: https://www.e-skills.com/Documents/Research/Insights-2012/, TechnologyInsights_2012_UK.pdf. Accessed 9 October 2015.

[4] P. J. Rich, N. Bly, K. R. Leatham, Beyond Cognitive Increase: Investigating the Influence of Computer Programming on Perception and Application of Mathematical Skills, Journal of Computers in Mathematics and Science Teaching, 33(1) (2014) 103-128.

[5] A. Lamprou, A. Repenning, N. A. Escherle. The Solothurn Project: Bringing Computer Science Education to Primary Schools in Switzerland, In Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education, ACM. (2017) 218-223.

[6] K. Kim, An Implications of Computer Education in Korea from the U.S., U.K. and Germany Computer Curriculums, Journal of The Korean Association of Information Education, 20(4) (2016) 421-432.

[7] Ministry of Education(2015). Practical Arts (Technical Assumption)/Information Curriculum. Ministry of Education Notice 2015-74 [Annex 10]. Sejong: Ministry of Education.

[8] J.Seo, C. Gu, Software education research school effectiveness analysis. Journal of the Korean Society for Computer Education, 23(1) (2018) 263-284.

[9] D. Ma, A Comparative Analysis Study on the Perceptions and Attitudes of Elementary School Teachers and Students on SW Education -Focusing SW education leading schools and general schools-,Journal of The Korean Association of Information Education, 25(1) (2021) 185-193.

[10] J. Park, An Analysis on the Current Status and Effectiveness of Software Education Leading School, Journal of Digital Contents Society 21(10) (2020) 1845-1854.

[11] S. Kim, et al., Development a Standard Curriculum Model of Next-generation Software Education, Journal of The Korean Association of Information Education, 24(4) (2020) 337-367.

[12] E. Lee, A Comparative Analysis of Contents Related to Artificial Intelligence in National and International K-12 Curriculum. Journal of Korean Association of Computer Education, 23(1) (2020) 37-44.

[13] J. You, et al., Elementary and secondary artificial intelligence education content system Exploratory Research Issues Report, KOFAC, (2020).

[14] S. Park, An Analysis Study of SW·AI elements of Primary Textbooks based on the 2015 Revised National Curriculum, Journal of The Korean Association of Information Education,25(2) (2021) 317-325.

[15] Y.Jeong, et al., A Development of the Software Education Curriculum Model for Elementary Students, Journal of The Korean Association of Information Education,19(4) (2015)467-480.

[16] K. Kim, et al., Development a Standard Curriculum Model of Next-generation Software Education. Journal of The Korean Association of Information Education, 24(4) (2020) 337-367.

[17] S. Ahnm S. L, Analysis of 2015 Revised SW Curriculum in Elementary and Middle School based on Core Competency, The Korean Society for Creative Information Culture, 5(1) (2019) 63-70.

[18] J. Kim, Current status and future of SW·AI education in secondary school. Communications of the Korean Institute of Information Scientists and Engineers, 39(9) (2021) 27-34.

[19] H. Woo, H. Lee, J. Kim, W. Lee, Analysis of Artificial Intelligence Curriculum of SW Universities. The Journal of Korean Association of Computer Education, 23(2) (2020) 13-20.

[20] D. Ma, Comparative study of SW education leading Middle & High schools and General school. Journal of Korean Association of Computer Education, 25(1) (2021) 157-164.

[21] S. Kim, J. Hong, D. Koo, J. Park, Y. Lee, Recognition of SW Education of Students, Parents, and Teachers in Elementary, Middle and High Schools: Focused on the SW Leading School, Journal of Korean Association of Computer Education, 23(6) (2019) 591-598.

[22] K. Oh, J. Kwon, A Study on the Verification of Computational Thinking Effectiveness of Understanding-Oriented SW Basic Education Program. The Society of Digital Policy & Management, 17(10) (2019) 23-35.

[23] S. Lee, J. Han, Analysis on Creativity and Solving-Problem Ability with Hackathon-based Elementary SW Education. Journal of Digital Contents Society, 18(5) (2017) 995-1000.

[24] S. Lee, Analyzing the effects of artificial intelligence (AI) education program based on the design thinking process. The Journal of Korean Association of Computer Education, 23(4) (2020) 49-59.

[25] J. Hong, Development and application of SW program based on Novel Engineering for improving the creative problem-solving ability of elementary students. Journal of Digital Contents Society, 19(12) (2018) 2315-2321.

[26] P. Kim, A Study on the Strengthening Method of SW Education Capacity for Pre-elementary School Teachers, International Journal of Computer Trends and Technology 69(1) (2021) 13-17.

[27] P. Kim, A Study on the Functionality and Effectiveness of SW Education Tools, International Journal of Computer Trends and Technology 68(1) (2020) 11-15.