International Journal of Engineering Education Vol. 39, No. 2, pp. 318–331, 2023
Printed in Great Britain
0949-149X/91 $3.00+0.00
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Status and Consulting Needs of K-12 Maker Education at Korean National Schools*

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Republic of Korea promotes maker education as a policy to enhance learners' engineering experience and problem-solving ability. This study was conducted for the purpose of examining the status of maker education operation and consulting needs of national elementary, middle, and high schools in Korea. To achieve this purpose, the research team operated the supportive group for maker education policy and collected and analyzed related data by conducting online and offline consulting, workshops, and surveys for maker education in all national schools (32 schools in total). The status of maker education is as follows. First, the student participation rate for maker education was high, but the teacher participation rate was relatively low. Second, the makerspace is built with an area of 1.5 to 2 times that of a general classroom, and supports various activities such as woodworking, digital manufacturing, software, and storytelling. Third, the makerspace is equipped with various equipment to support the activities of learners. Fourth, the maker education is centered on technology, science, and information subjects. Fifth, teachers generally perceive the effect of maker education positively. The consulting requirements of maker education are as follows. First, teachers have difficulties in securing and reorganizing space. Second, teachers have difficulties in purchasing and managing materials, tools, and equipment related to the curriculum. Third, teachers requested various maker education programs that can be applied to the curriculum. Fourth, teachers are paying a lot of attention to the safety issues of makerspaces. Fifth, teachers suggested the need to increase the understanding of maker education among school members. Given the implications of the study, the establishment of a systematic support system for maker education, the preparation of a curriculum for engineering experience, and the development of equipment making tools suitable for schools were recommended.

Keywords: maker education; maker space; consulting needs; K-12; Korea

1. Introduction

Technologies in the era of the 4th industrial revolution, such as AI, big data, and the Internet of Things (IoT), are rapidly changing our society. To respond to changes given a complex and uncertain future society, schools have prepared for future education with competency-based education. Learners should have the ability to practically solve complex problems using higher-order thinking skills [1]. Because the influence of technology is growing, many countries are putting a lot of effort into engineering education to develop engineering problem-solving capabilities. In engineering education, learners can develop various future core competencies by imitating and experiencing problem-solving processes performed by engineers in real science and technology fields or industrial fields.

In Korea, STEAM education and maker education are actively promoted as representative policies related to engineering education. STEAM education has been applied to K-12 education from 2011 to the present. STEAM education emphasizes creative design to stimulate interest and motivation in science and technology fields [2]. Creative design emphasizes the fusion of knowledge and self-directed problem solving to answer the question of 'how'. STEAM education has been widely applied in most schools in Korea for over 10 years [3]. On the other hand, STEAM education had difficulties in allowing students to experience the ideal problem-solving process in the school field. Although 'creative' activity is emphasized in the design of STEAM education, in many cases, students' problem-solving process was limited to presenting ideas due to the lack of equipment, space, and budget [4].

Meanwhile, as the maker culture spreads around the world, school education has also begun to pay attention to active 'creative' activities using various materials, tools, and equipment [5]. Students solve problems through crafting activities using a variety of materials, tools, and equipment in the makerspace. Students generate various ideas to solve problems, collaborate with others, and find optimal solutions through iterative prototyping [6, 7]. In the makerspace, students perform design, production, and sharing activities, and can experience various making such as craft, woodworking, electrical and electronic, modeling, art, and media. A K-12

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* Accepted 21 December 2022.

makerspace is a useful place for students to develop STEAM-related and innovation skills by experiencing the problem-solving process of an engineer [8]. In addition, maker education has been shown to have great educational effects such as academic achievement, collaboration, and problem-solving ability, and has a greater learning effect, especially when engineering problem-solving processes are integrated [9].

In Korea, attention is paid to the value of maker education and efforts are being made to revitalize maker education in the K-12 level [10]. In 2017, the Ministry of Education presented maker education with the goal of nurturing creative convergence talent, and is promoting the expansion of makerspaces, development of maker education programs, and teacher competency development. In addition, many provincial and provincial education offices have established mid- to long-term strategies for maker education in units of 4 to 5 years and are establishing makerspaces in many schools.

It is necessary to examine the operating status of maker education at the time that maker education was introduced in Korean schools five years ago. Furthermore, teachers still face difficulties in implementing maker education, such as securing space, operating devices, and complex instructional design [11, 12]. The government needs to know their consulting needs. To find out the status of maker education and consulting needs among all 32 national schools in Korea, a maker education supportive group was operated to support consulting and workshops for the schools. The results were derived by qualitative and quantitative analysis of the reports and survey results collected here. By examining the status of maker education and the need for consulting, we would like to suggest policy and research implications for the sustainable practices in schools.

2. Literature Review

2.1 Korea's K-12 Maker Education Policy

Interest in the maker movement, the creation and sharing of something, is growing worldwide [13]. Makers participating in maker activities solve personal or social problems through voluntary sharing activities. These maker movements have developed in diverse forms, such as participation in online communities, activities in makerspaces, and participation in maker fairs [14]. Various activities in the making process have various learning effects such as STEM ability, entrepreneurship, and creativity [15]. For this reason, countries around the world are making various efforts to implement maker education on the K-12 level.

In Korea, several government ministries have been actively implementing maker education since 2017 [10]. As part of creative and convergence education, the Ministry of Education supports the development of maker education programs, teacher training, and establishment of makerspaces, while the Ministry of Science, Technology and Information and Communication supports the establishment of Makerspaces in universities and public facilities for all citizens. And the Ministry of SMEs and Startups is making efforts to spread the maker culture and support the startup ecosystem. In addition to these government ministries' efforts, 17 provincial and provincial education offices in Korea are implementing maker education in various ways [10]. Representatively, Seoul and Busan Metropolitan Office of Education announced mid-term and long-term development plans for maker education. In November 2017, the Seoul Metropolitan Office of Education announced the Seoul-type Maker Education (tentative name 'Future Workshop Education') mid-term and long-term (2018–2022) development plan, and announced that it would be implemented in stages from 2018 [13]. Imagining, making, and sharing Seoul-style maker education (tentative name 'Future Workshop Education') is a new educational paradigm for nurturing 'maker geeks' who can create something on their own. It is a process-oriented project education that leads people to create their own using a variety of tools and to share the knowledge and experience acquired in the process with others. The project is scheduled to invest about 2.8 billion won in 2018, and about 10 billion won was spent over the next five years. Major activities include the operation of a make bus to visit, the maker geek festival, and the development of AI-linked maker education materials. The Busan Metropolitan Office of Education announced the Five-Year Plan for Creative Convergence Education based on Busan-type Maker Education to nurture future talents with creativity and challenging spirit [14]. The plan contains four key tasks: 'Expansion of makerspace in schools,' 'Establishment of vertical and horizontal maker education system,' 'Establishment of Imaginary & Creative School,' and 'Holding of Creative Convergence Festival.' The Busan Office of Education is expanding the makerspace currently operated by 97 schools to all elementary, middle and high schools in Busan by 2022. Major activities include establishment of maker education hubs by region, business agreements with universities and maker education, and holding of maker education camps.

2.2 Characteristics of K-12 Maker Education in Korea

The characteristics of K-12 maker education in Korea can be summarized as follows.

First, each school has established a makerspace to support creative and expressive activities. In order to facilitate the use of various materials, tools, and equipment in maker education, the existing technology laboratory or STEAM laboratory has been improved or a separate space is provided. Makerspaces have been established in all national schools in Korea (32 schools in total) and a number of public and private schools, and support various materials, tools, and equipment such as 3D printers, laser cutters, and woodworking equipment. 3D printers are widely used and 18,324 3D printers were distributed in 5,222 schools (43.45% of the total) as of 2020 [15]. The Office of Education is supporting the establishment of an environment such as space construction guidelines and 3D printer safety guidelines for the establishment of a makerspace [16]. In particular, a make space is being built as an essential space in a newly built futuristic school. This space is a central space connected to the library and classroom and is expected to support various activities such as idea derivation, discussion/discussion, experiment/practice, and creation [17].

Second, maker education has been practiced in the form of engineering problem solving process, design thinking, and project learning in Korea. Teachers provide opportunities for students to look at problems from an engineering perspective and use tools effectively in the problem-solving process. In addition, students have an opportunity to solve real problems by making visible products and opening them to a specific audience. Through the problem-solving process, students understand the concepts, principles, and application methods of engineering and develop core competencies for the future. To support these activities, the Office of Education is developing and distributing teaching and learning materials focused on problem solving.

Third, maker education in connection with school and community resources has been attempted. Makerspaces are established in libraries, museums, universities, and startups around the school, and maker education is provided in connection with K-12 schools [18]. In schools, students can visit specific makerspaces and receive free education or borrow related materials, tools, and equipment to use in class. The government is providing the relevant budget to support these activities. Some local governments, such as Osan city, have established maker education centers to provide maker education programs for students and parents, or conduct professional development programs for teachers. The Office of Education is creating various opportunities such as maker festivals, forums, and experiences in connection with the local community because it is important to form a maker culture in maker education [19].

Fourth, maker education is being conducted online or in a blended format. In a situation where makerspaces were established in many schools and maker education was activated, a pandemic was encountered. COVID-19 has forced many schools to switch to distance learning or blended learning. In the COVID-19 situation, offline maker education was greatly reduced, but teachers practiced maker education online or in blended. Teachers conducted online education on the understanding of subject content and how to operate the machine, and offline classes were conducted on the production of works using a laser cutting machine and the use of woodworking equipment [20]. In addition, teachers actively practiced expressing their thoughts or creating products in the digital space using meta-verse and NFT [21].

Firth, maker education attracts attention as it represents a paradigm shift in teaching and learning rather than in a specific area [25]. In general, maker education focuses on developing technological literacy and problem-solving abilities, while maker education focuses on creating, sharing, and communicating based on the maker spirit. Maker education is not a specific subject area, but rather expands teaching and learning. For this reason, Korean policy recommends maker education as a teaching learning method for future education [26].

Various attempts are being made to implement K-12 maker education policies in Korea, but they are facing several problems.

First, as makerspaces are built in many schools, difficulties arise in utilization and management. As the makerspace is equipped with a variety of materials, tools, and equipment, and as more and more equipment requires expertise to operate, it is difficult for teachers to manage by themselves. Most of the makerspaces are managed by a single teacher without a separate management person. The difficulty of managing the makerspace is limiting the time students can use it or hindering the use of other teachers. In addition, if there are no teachers who are interested in and professional in maker education, the space utilization rate is very low.

Second, there are difficulties in developing the competency of teachers to implement maker education. The main reason that teachers' competency development is difficult is that they require high-level technological and engineering knowledge. Teachers should be able to guide students in the use of materials, tools, and equipment so that they can effectively implement their ideas, and to provide immediate support when problematic situations arise. In addition, it should help learners to properly integrate technology into their making process. In this situation, teachers need Technological Pedagogical Content Knowledge (TPACK) with expanded Technological Knowledge (TK) and Technological Content Knowledge (TCK) as shown in Fig. 1 [4]. In maker education, teachers must be able to handle technology proficiently with content and methods. However, for teachers other than science and technology, there is a limit to the application of technology knowledge such as 3D printers, laser cutting machine, woodworking equipment, etc. as contents knowledge. These teachers will not adopt maker education into their subject if it requires many types of high-level technology knowledge.

Third, maker education is dependent on a teacher's hobbies, interests, and personal capabilities. Although it seems that various programs are operated in many schools, the actual program operation often depends on the interests of the teachers in charge. For example, if the teacher in charge has a hobby of making furniture, the main activity of maker education is likely to be woodworking. Whereas, if a teacher in charge is interested in coding, the main activity will be SW-related activities. Maker education without a content system has limitations in providing students with various production experiences. And maker education without a systematic content has difficulty in providing different levels of production experience depending on the developmental level of students. In addition, teachers outside of STEM-related subjects lack interest and awareness about maker education. These teachers perceive that it is appropriate to apply maker education to creative experiential activities such as club activities and free grade system rather than to apply maker education to

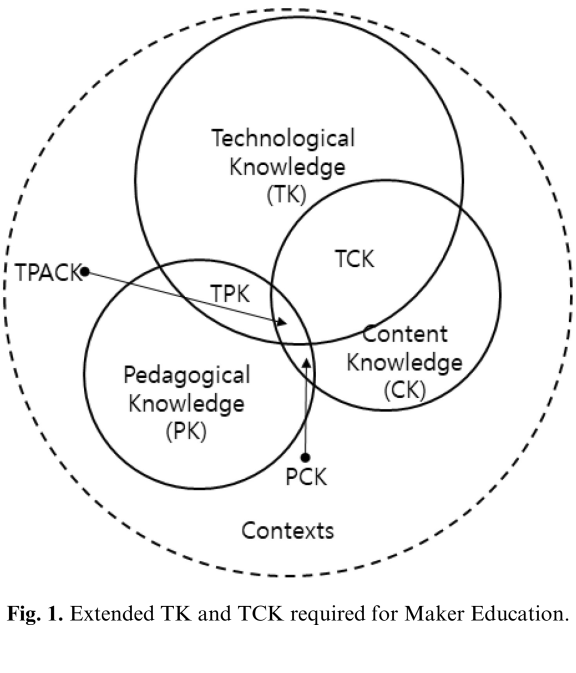

Fig. 1. Extended TK and TCK required for Maker Education.

subjects [22]. It is becoming a limiting factor in integrating maker education in various subjects.

Fourth, maker education is operated in a limited form centered on coding or ICT. Maker education consists of various activities such as crafts, woodworking, coding, electricity/electronics, and arts [23, 24]. The reasons for this are the emphasis on SW and AI education and the reduction of teaching burden due to relatively simple class preparation. In order to conduct classes such as crafts and woodworking, teachers are burdened with preparing a lot of materials and handling complex equipment, but coding has the ease of being easily executed if only a computer is equipped. On the other hand, the biased maker education may have limitations in providing students with various engineering experiences.

3. Method

3.1 Research Procedure

The research procedure and methods as shown in Fig. 2 were applied to find out the status of K-12 maker education and the consulting needs. First, the maker education supportive group was formed to support 32 national schools across the country. The supportive group conducted workshops and consulting to support maker education in national schools. Based on the output collected in the consulting process, the status of maker education and consulting needs were analyzed.

3.2 Schools and Participants

This study was conducted for a total of 32 schools (elementary school: 16 schools, middle school: 7 schools, high schools: 9 schools) that correspond to all national schools in Korea. National schools are implementing maker education with support from the Ministry of Education to build a makerspace and equip them with necessary equipment. The makerspace was built in 2019 for middle school, 2020 for elementary school, and 2021 for high school. These schools have established different types of makerspaces in line with the maker education programs and are operating various maker education programs on their own in consideration of the context of the school and the competence of teachers. Key characteristics of the schools and participants in this study are shown in Table 1.

3.3 Maker Education Support Group

From May 2021 to January 2022, the researcher provided consulting for the implementation of maker education in national schools as the maker education support group of the Ministry of Education. The support group consisted of a total of 32 people, including professors, teachers, and experts who have extensive experience in research and

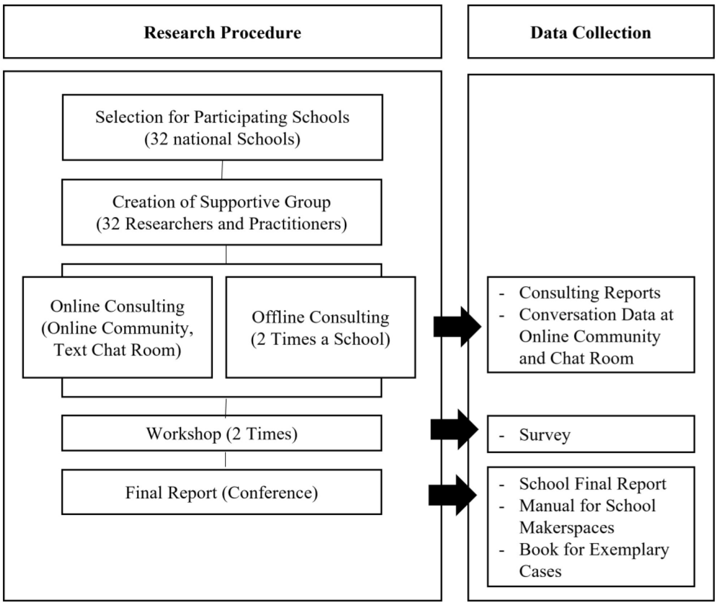

Fig. 2. Research Procedure and Data Collection.

Table 1. Characteristics of the Participants

Number	School	Region	Total		Participation for Maker Education		Size of Maker-spaces (m^2)	Period
			Students	Teachers	Students	Teachers		
1	Elementary School 1	Seoul	605	36	605	7	120.69	2nd (2020~)
2	Elementary School 2	Busan	640	33	640	8	187.2	2nd (2020~)
3	Elementary School 3	Daegu	556	34	556	15	114.75	2nd (2020~)
4	Elementary School 4	Daegu	437	26	437	24	103.6	2nd (2020~)
5	Elementary School 5	Incheon	576	33	576	10	135	2nd (2020~)
6	Elementary School 6	Gwangju	580	26	580	11	88	2nd (2020~)
7	Elementary School 7	Chuncheon	420	26	420	10	200	2nd (2020~)
8	Elementary School 8	Cheongju	430	23	430	10	99.5	2nd (2020~)
9	Elementary School 9	Cheongju	494	33	494	32	86	2nd (2020~)
10	Elementary School 10	Gongju	499	30	499	30	101.25	2nd (2020~)
11	Elementary School 11	Andong	418	24	418	28	105	2nd (2020~)
12	Elementary School 12	Jeonju	434	25	434	6	99.1	2nd (2020~)
13	Elementary School 13	Gunsan	430	26	430	24	126	2nd (2020~)
14	Elementary School 14	Mokpo	430	34	430	9	101.25	2nd (2020~)
15	Elementary School 15	Jinju	557	31	557	4	168.75	2nd (2020~)
16	Elementary School 16	Jeju	430	26	430	26	101.25	2nd (2020~)
17	Middle School 1	Daegu	555	42	369	4	202.5	3rd (2019~)
18	Middle School 2	Gwangju	218	31	159	8	120	3rd (2019~)
19	Middle School 3	Cheongju	479	41	479	11	101.25	3rd (2019~)
20	Middle School 4	Cheongju	378	60	378	6	270	3rd (2019~)
21	Middle School 5	Gongju	171	22	171	6	67	3rd (2019~)
22	Middle School 6	Jinju	525	37	525	6	150	3rd (2019~)
23	Middle School 7	Jeju	670	55	267	11	135	3rd (2019~)
24	High School 1	Gwangju	622	66	394	8	98.55	1st (2021~)
25	High School 2	Jeonju	690	57	690	5	135	1st (2021~)
26	High School 3	Gongju	494	52	358	8	235	1st (2021~)
27	High School 4	Daegu	775	73	263	14	156.5	1st (2021~)
28	High School 5	Cheongju	319	36	193	8	81.34	1st (2021~)
29	High School 6	Jinju	430	45	249	6	184.8	1st (2021~)
30	High School 7	Busan	525	70	347	14	56	1st (2021~)
31	High School 8	Jeju	685	59	149	6	265	1st (2021~)
32	High School 9	Cheongju	513	47	154	7	129.6	1st (2021~)

implementation of maker education. The activities of the support group consisted of the following procedures. First, the support group established an online/offline consulting system for effective consulting. The support team established an online community and group text chat room to provide online consulting regardless of time and space. The support group provided various materials necessary for maker education such as space, programs, and safety to the online community, and provided a place for teachers to share related information. The support group conducted offline consulting based on a survey on the demand for consulting by school. Three consultants were assigned to provide one or two consulting sessions per school. The consulting took a total of 90 to 120 minutes and was conducted both online and offline in consideration of the COVID-19 situation. The support group recorded and transcribed the consulting conversation and wrote the consulting result by each school. Second, the support group provided teachers' capacity building programs. The support group operated two workshops and one performance sharing session. The program consists of programs that can support on-site teaching and learning, such as the use of 3D printers, management of woodworking equipment, and artificial intelligence class cases. Third, the support group conducted a survey on the operation status of each school. The questionnaire consisted of a total of 22 questions asking about usage status, space type, equipment owned, class activities, educational operation, and safety. Fourth, the support group developed a makerspace operation manual and best practice book based on the operation results. The book was distributed into the school teachers in both online and hardcopy versions.

3.4 Data Collection and Analysis

This study collected and analyzed data based on the research question. First, to find out the status and perception of maker education, a survey of actual status and the final result report for each school were analyzed. The results of the survey were presented as descriptive statistics, and the result reports of each school were analyzed. In the survey, one teacher in charge of each school responded to the question asking about the actual status, and 118 teachers (39 elementary school teachers, 39 middle school teachers, 40 high school teachers) participating in the maker education responded to the question about perception. Second, content analysis was conducted on consulting result reports, online posts, and group texts to find out the needs of maker education consulting. Excel was used for descriptive statistical analysis and content analysis. Table 2 shows the questionnaire questions and analysis frame to find out the status and perception of maker education.

4. Results

4.1 Status and Perception of Maker Education

4.1.1 Participatory Status

The average number of participating students by school was 496 (100%) elementary school students, 335 middle school students (78.37%), and 310 high school students (55.4%). The average number of participating teachers by school was 15.9 in elementary school (54.50%), 7.4 in middle school (18.05%), and 8.4 in high school (15.05%). It was found that the average number of students participating in each school and the number of teachers decreased as the school level increased.

Table 2. Data collection and analysis

Category	Analysis	Question Item	Sources
Status and perception of maker education	Number of participation	• Number of participation (Students)	• Final report
		• Number of participation (Teachers)	• Final report
	Space	• Space type (Possible in multiple responses)	• Survey
		• Area	• Final report
	Equipment	• Type and number of equipment	• Survey
	Teaching and learning	• School subject (Possible in multiple responses)	• Survey
		• Instructional types	• Survey
		• Number of professional developments	• Final reports
	Perception toward the effects	• Creativity, problem solving, collaborative or communication ability, self-directed learning competency, convergence thinking competency, Subject knowledge	• Survey
Consulting needs		• Establishing space (makerspaces)	• Consulting report • Conversation data at group platform
		• Securing and managing equipment, tool, material	
		• Program implementation	
		• Safety management	
		• Teachers' professional development	

Table 3. Status of makerspaces in national schools

Types		Elementary school	Middle School	High School	Total
Space types (Possible in multiple responses)	Woodworking	5	7	3	15
	Digital equipment	9	2	5	16
	SW oriented	7	3	6	16
	Storytelling	1	0	4	5
Average areas		121.08 m^2	149.39 m^2	149.09 m^2	

4.1.2 Status of Makerspaces

Table 3 shows the status of makerspaces built in national schools. First, according to the survey on the makerspace type, 9 elementary schools using digital equipment type, 7 SW-oriented schools, 5 woodworking schools, and 1 storytelling type school. Among middle schools, 7 woodworking-type schools, 2 digital equipment-type schools, and 3 SW-oriented schools appeared in that order. As for high schools, there were 6 SW-centered schools, 5 digital equipment schools, 4 storytelling schools, and 3 woodworking schools. Overall, it can be seen that the more common makerspaces are SW-oriented, digital equipment, and woodworking types. However, multiple responses were possible for this question, and there are many schools with two or more spaces. Next, in the results of the survey on the area of the makerspace, it was found to average 149.39 m^2 for middle schools, 149.09 m^2 for high school, and 121.08 m^2 for elementary school. As a point of reference, the typical classroom in Korea is 70~80 m^2, so makerspaces are approximately 1.5~2 times the size of a regular classroom.

4.1.3 Status of Equipment in Makerspaces

Table 4 shows the status of makerspace equipment in national schools. First, as a result of a survey on the status of woodworking equipment, about 50% of elementary schools own electric drills and laser engravers. More than 70% of middle schools own woodworking equipment such as electric drills, table saws, and electric sander. High schools have electric drills and laser engravers in less than 50% of schools. Next, as a result of a survey on the status of digital manufacturing devices, elementary schools own 50% of 3D printers and 31.25% of 3D pens. In middle school, all schools have 3D printers, and 42.86% of schools have 3D pens. High schools own 66.67% of 3D printers and 33.33% of 3D pens. Next, as a result of the survey on the status of ICT equipment possession, 31.25% of elementary schools own computers and 43.75% of automatic charging boxes. Middle school has 100% computers and 71.43% Arduino. High school owns 77.78% of computers and 77.78% of Arduinos. As a result of the survey on the status of video production equipment, 31.25% of elementary schools have teleconference facilities and 18.75% of video production cameras. Middle schools own 71.43% of teleconference facilities and 42.86% of video production cameras. High schools own 44.44% of video production cameras and 33.33% of video conferencing facilities.

4.1.4 Status of Implementing Maker Education

First, elementary schools were in the order of practical arts/technology and home-economics (12 schools), science (10 schools), and fine art (6 schools). Middle schools were ranked in the order of for practical arts/technology and home-economics (7 schools), science (3 schools), and mathematics (3 schools). High schools were ranked in the order of science (5 schools), practical arts/technology and home-economics (3 schools), and computer and information (3 schools). It is widely applied in practical arts/technology and home-economics and science subjects at all school levels and is applied to art subjects in other elementary schools, mathematics subjects in middle schools, and information subjects in high schools. In the survey on class activity types (see Fig. 3), it was found that elementary schools devote 18% to teacher-centered theory classes, 46% to student-centered activities, 17% to student presentations and discussions, and 19% to exhibit and sharing works. Middle schools devote 21% to theory classes, 41% to making activities, 16% to presentations and discussions, and 22% to exhibit and share works. High schools devote 31% to theory classes, 33% to making activities, 13% to presentation and discussions, and 23% to exhibit and share works. As the school level increases, the proportion of teacher-centered theory lectures increases, and student-centered activities decrease. The number of teacher training for strengthening maker education competency was 5 times in elementary school, 5.43 times in middle school, and 4.33 times in high school.

4.1.5 Teachers' Perception of the Effect of Maker Education

Table 5 shows teachers' perceptions of the effects of maker education in national schools. Teachers' perception of creativity appeared in the order of middle school, elementary school, and high school. Teachers' perception of problem-solving ability was in the order of elementary school, middle school, and high school. Teachers' perceptions of coopera-

Table 4. Status of equipment in makerspaces

Category	Equipment	Elementary School (%)	Middle School (%)	High School (%)
Wood working	Electric Drill	8(50.00)	7(100.00)	4(44.44)
	Drill Press	5(31.25)	5(71.43)	3(33.33)
	Electric Sander	5(31.25)	6(85.71)	3(33.33)
	Angle Cutter	4(25.00)	4(57.14)	2(22.22)
	Band Saw	3(18.75)	4(57.14)	3(33.33)
	Jigsaw	4(25.00)	5(71.43)	1(11.11)
	Table Saw	5(31.25)	6(85.71)	1(11.11)
	Unimat	0(0)	1(14.29)	0(0)
	Laser Engraving Machine	2(12.50)	4(57.14)	2(22.22)
	Laser Engraver	7(43.75)	4(57.14)	4(44.44)
	CNC Equipment	2(12.50)	1(14.29)	0(0)
	Paper Cutter	5(31.25)	2(28.57)	1(11.11)
	Ventilation Equipment	8(50.00)	5(71.43)	4(44.44)
	Dust Collector	7(43.75)	6(85.71)	3(33.33)
Digital Making	3D Printer	8(50.00)	7(100.00)	6(66.67)
	3D Pen	5(31.25)	3(42.86)	3(33.33)
	3D Scanner	5(31.25)	1(14.29)	1(11.11)
	UV Printer	3(18.75)	0(0)	0(0)
	Sublimation Imprinter	4(25.00)	2(28.57)	2(22.22)
ICT	Computer	5(31.25)	7(100.00)	7(77.78)
	Robot Set	0(0)	3(42.86)	3(33.33)
	Arduino	2(12.50)	5(71.43)	7(77.78)
	Automatic Charing Box	7(43.75)	4(57.14)	6(66.67)
	Drone	3(18.75)	3(42.86)	2(22.22)
	VR Device	3(18.75)	1(14.29)	3(33.33)
Video Making & Others	Teleconference Facility	5(31.25)	5(71.43)	3(33.33)
	Video Production Camera	3(18.75)	3(42.86)	4(44.44)
	Gimbal	1(6.25)	3(42.86)	0(0)
	Green Screen	3(18.75)	3(42.86)	3(33.33)
	Bon Sewing Machine	0(0)	1(14.29)	2(22.22)
	Overlock Sewing Machine	1(6.25)	0(0)	0(0)

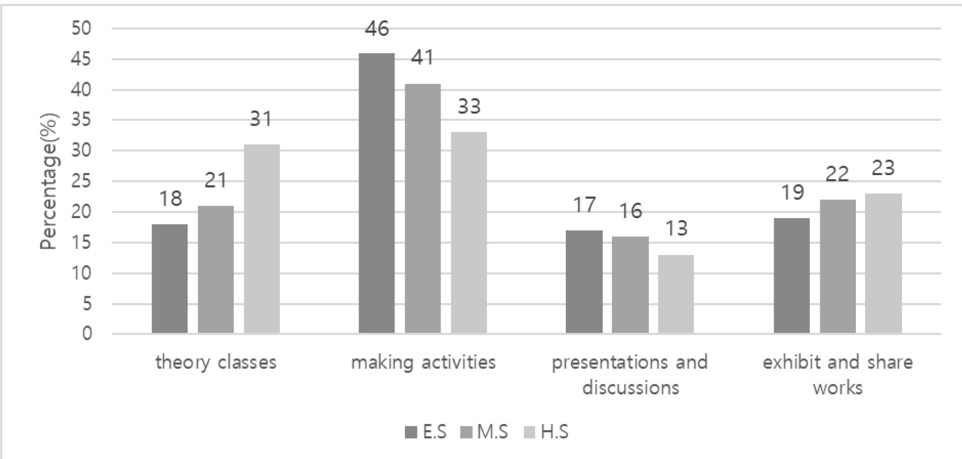

Fig. 3. Class activity type in maker education.

tion and problem-solving ability were in the order of middle school, elementary school, and high school. Teachers' perception of self-directed learning ability was in the order of middle school, elementary school, and high school. Teachers' perceptions of convergence thinking ability were in the order of middle school, elementary school, and high school. Teachers' perception of subject content comprehension was in the order of middle school, elementary school, and in high school. As a result of the F test, it was found that there were significant differences by school level in teachers' perceptions of creativity, problem solving ability, cooperation and communication ability, self-directed learning ability, and convergence thinking ability. As a result of the post-test (Scheffe), middle school and elementary school teachers perceived the maker education effect more positively than high school teachers.

4.2 Consulting Needs for Maker Education

Table 6 shows the frequency of requests for consulting in the process of implementing maker education in Korean national schools. The consulting needs in terms of space construction and operation of the makerspaces are as follows. First, teachers asked for consulting on securing space to build a maker space and linking with other spaces. Teachers had difficulties in securing a relevant space for implementing maker education in the existing school space. There was no free space in the school, so we had to think about changing the use of existing classrooms or school spaces, and some schools (E3 and E4) built a makerspace in an underground space with poor ventilation and lighting. And although the teachers wanted the maker space to serve as a central space to support creative activities, it was difficult to arrange it as a central space in the various spaces that have already been built. Second, teachers had difficulties in reorganizing the space according to various issues. Maker education is facing various safety issues such as the emission of hazardous substances in the 3D printing process, the risk of fire from equipment using high heat, and the risk of cutting of processing equipment. In Korea, to respond to these safety issues, it is emphasized that the equipment should be in a separate space with good ventilation and disaster prevention. However, since many makerspaces do not have enough free space, teachers are having difficulty reconstructing existing spaces or securing idle space.

Table 5. Teachers' perception on the effects of the maker education

Type	Elementary School M(SD)	Middle School M(SD)	High School M(SD)	*F(p)*
Creativity	4.56 (0.58)	4.71 (0.46)	4.12 (0.77)	5.51(0.007) b=a>c
Problem solving	4.59 (0.57)	4.58 (0.58)	4.15 (0.73)	3.43(0.040) b=a>c
Collaborative & Communication	4.56 (0.64)	4.71 (0.55)	4.31 (0.55)	3.34(0.043) b=a>c
Self-directed learning	4.59 (0.57)	4.63 (0.58)	4.08 (0.80)	4.53(0.016) b=a>c
Convergence thinking	4.52 (0.64)	4.67 (0.56)	4.27 (0.53)	3.33(0.044) b=a>c
Subject knowledge	4.33 (0.83)	4.42 (0.78)	3.84 (0.94)	3.00(0.059)

Table 6. Result of analysis on consulting needs for maker education

Type	Category	Frequency (%)	
		Offline Consulting	Online Consulting
Space construction and management	Securing spaces for makerspace and connecting with other school spaces	26(16.15)	–
	Reconstructing school spaces for related issues	17(10.56)	–
Securing & Managing material, tool, equipment	Purchasing material, tool, equipment for school curriculum	23(14.29)	9(33.33)
	Securing budget for purchasing material, tool, equipment	7(4.35)	8(29.63)
	Strategies to use the equipment in school makerspaces	1(0.62)	5(18.52)
Implementing programs	Developing relevant program for maker education	19(11.80)	5(18.52)
	Designing collaborative convergence class	7(4.35)	–
	Managing program for COVID-19 (Online/blended)	5(3.11)	–
Safety management	Guideline for planning and implementing safety strategy	22(13.66)	–
	Professional knowledge on firefighting, electricity, ventilation	18(11.18)	–
	Safety management for unexpected situations	6(3.73)	–
Professional development for teachers	Managing teachers' learning community in schools	7(4.35)	–
	Colleague's Understanding and concern toward maker education	3(1.86)	–
	Total	161(100)	27(100)

Consulting needs in terms of materials, tools, equipment acquisition and operation are as follows. First, teachers requested consulting on the purchase of materials, tools, and equipment related to the curriculum. Maker education consists of various activities such as crafts, woodworking, coding, electricity/electronics, media, and art. I had. Teachers asked or shared their experiences of using 3D printers, laser cutting machines, and woodworking equipment through online text messages. Because there are not enough reviews on maker education equipment, the experiences of fellow teachers and methods of applying teaching and learning are becoming important criteria for selecting equipment. Second, teachers requested consulting on securing and utilizing the budget. Although various materials, tools, and equipment are required in maker education, teachers could not predict the maker education activities of other teachers and thus could not secure a budget. In addition, teachers presented a problem that the budget was insufficient to respond to safety issues in the makerspace. In addition, teachers had difficulties in using the budget due to the regulations of the Office of Education, which enforced the budget only within a certain area and scope. Third, teachers asked for consulting on the use of programs and equipment. Some equipment often requires specialized knowledge to operate, but teachers had a hard time learning how to use all the equipment. For this reason, many questions were posted in the group chat room asking about the operation and utilization of programs or equipment.

> "I am preparing to purchase a 3D pen. There's a rumor that it's going to break. If there is a 3D pen that you are using, can you share it with a product that you are highly satisfied with? Please help me use the laser cutting machine. I am using 6T birch plywood. When I set the speed to 8 and the maximum power to 65, the front plate burns, and the rear panel cannot be cut." (Maker Education Teachers' Group Chat for Online Consulting Platform)

Consulting needs in terms of maker education program operation are as follows. First, teachers requested consulting on program development and exploration for maker education. Teachers searched for videos and learning materials that could be used in the teaching and learning design process. Also, I thought a lot about what materials, tools, and equipment could be used in the teaching and learning process. Second, teachers requested consulting on cooperative lesson design for convergence lessons. Maker education, which is conducted as a project, has many convergence activities, so many teachers design and implement classes together. At this time, teachers requested examples of convergence classes or related materials that they could refer to. Third, there was a request for consulting on program operation according to the COVID-19 situation. Making activities often require students' cooperation and communication, but the risk of infection with COVID-19 has limited such activities. For this reason, maker education was hardly implemented in the early days of COVID-19, but after distance classes were activated, efforts were made to try maker education through digital making and blended learning. Teachers requested a maker education program that could be applied in a blended situation.

> "I am trying to make a Bluetooth speaker with my own design with a laser cutter. Please recommend a program that students can learn and design the most easily. Also, if you have a site or material with basic designs (speakers, bookshelves, jewelry boxes, etc.), please share it." (Maker Education Teachers' Group Chat for Online Consulting Platform)

Consulting needs in terms of safety management are as follows. First, teachers requested consulting for information and guidance on establishing safety plan. The maker space is equipped with a variety of equipment, making it difficult for teachers to identify all the hazards. Teachers requested guides and checklists for safety management plans that can be applied as a standard. Second, teachers requested consulting on safety-related expertise. Teachers had difficulties in building a safe makerspace due to lack of expertise in firefighting, electricity, ventilation, and movement. There are many cases where ventilation and disaster prevention are required for each equipment, and this problem was found in offline consulting. Third, teachers requested consulting on safety management in unexpected situations that may occur during the making process. In the making activity, various problem situations such as bumps, falls, pranks, and damage during movement may occur. Teachers asked for posts and autographs to prevent such problematic situations.

> "Insufficient safety cover installation in various charging facilities, and the safe treatment of dust and harmful substances generated when using 3D printers and laser cutting machines." (M15 Offline Consulting Result Report)

> "There is a risk factor in terms of safety management because many machine tools are arranged in a small space. In addition, there is a risk of fire because equipment using high power is concentrated. It is necessary to carry out electrical work to have a power cut-off facility." (M5 Offline Consulting Result Report)

Consulting needs in terms of teacher professional development are as follows. First, consulting on the operation of a learning community in schools for maker education was requested. Efforts were made to implement convergence-oriented maker education through a voluntary professional learning community. Second, consulting was requested on the enhancement of understanding and interest in maker education among members of the school. Teachers presented as a problem the lack of understanding of maker education other than participating teachers. It was hoped that training programs would be recommended for the professional development of teachers, and professional instructors would be matched. In addition, it was requested to raise the awareness of teachers through publicity about maker education.

5. Discussion

The discussion on the status and perception of maker education in national schools is as follows. First, it was confirmed that the number of participating students decreased as the school level increased. This can be interpreted that the number of students participating in the maker education is small in elementary schools because there is an emphasis on craft and activity-oriented classes and there are many integrated classes, so maker education can be easily integrated. In Korean high schools, classes tend to focus on university entrance exams, which is interpreted as lowering the participation rate. In addition, the number of teachers participating in maker education is less than 20% in middle and high schools. This suggests that it is necessary to increase the understanding of maker education for teachers and to develop various programs that can be applied to subjects other than science and engineering. Second, it can be confirmed that various types of makerspaces have been established to support students' maker education. In elementary school and high school, woodworking type, digital equipment type, and SW-centered type were built evenly, and it can be confirmed that it was built with woodworking type at middle school. This can be interpreted that the AI education policy has been emphasized in Korea recently, and this trend is reflected in the relatively recently established makerspaces of elementary and high schools. The size of the makerspace was found to be 1.5 to 2 times the size of a general classroom. To support smooth making, it is necessary to secure sufficient space for activity, storage, sharing, rest, and safety. Schools need to analyze learners' activities and review whether sufficient space is secured [16]. Third, the makerspace is equipped with various equipment to support the activities of learners. Particularly, elementary and middle schools were equipped with woodworking, digital manufacturing equipment, and ICT equipment in a balanced way. On the other hand, high schools have a relatively high ratio of computers, 3D printers, and Arduinos. In high school, it is necessary to comprehensively support analog and digital making so that students can experience various engineering problem solving processes. Fourth, it can be confirmed that the maker education is centered on technology, science, and information subjects. In the sense that maker education requires high technological knowledge, it can be interpreted that the approach is focused on related subjects. In addition, it is necessary to support various programs so that convergence classes can be conducted centered on technology, science, and information subjects. In addition, it is necessary to develop making equipment that can be easily applied in general subjects. Fifth, it was found that teachers generally perceived the effect of maker education positively. Relatively, high school teachers perceived the effect of maker education as low, which is interpreted as the short execution period of maker education and insufficient discovery of the educational effect. In terms of subject content comprehension, high school scored 3.84, which can be interpreted as a perception that high school teachers have little relevance to university entrance exams.

Next, the discussion on the maker education consulting needs of national schools is as follows. First, teachers have difficulties in securing and reorganizing space. In Korea, the spatial organization of a makerspace is dependent on the teacher in charge. If the teacher in charge does not have a sufficient understanding of the makerspace, it may be difficult to secure and organize the space. In addition, there are many cases where the space is restructured due to the direction of the school's maker education and various safety issues. To support this, it is necessary to provide expert help and customized consulting on building a makerspace. Second, teachers have difficulties in purchasing and managing materials, tools, and equipment related to the curriculum. There is various equipment used in maker education, so if you do not have information on equipment and experience in using it, you may have difficulties in purchasing and using it. Insufficient knowledge and experience of using technology are the main difficulties in implementing maker education. The education office needs to provide a list of standardized equipment for each making activity or support customized training for related equipment. Third, teachers requested various maker education programs that can be applied to the curriculum. To implement the maker education program, teachers are making great efforts to search for class materials on blogs, YouTube, etc. or to obtain related information. In addition, because learner-led lessons need to be designed, complex and integrated lesson design capabilities are required. In this case, cooperation with teachers or experts is essential. The education office needs to provide a cooperative class design experience for maker education or provide a variety of programs to increase teaching effectiveness. Fourth, teachers are paying a lot of attention to the safety issues of makerspaces. Many of the equipment introduced into the makerspace are recently developed and often do not undergo sufficient stability testing. Problems with the emission of hazardous gases from 3D printers, overheating of laser cutting machines, and dust generation when processing wood can put students at risk. It is time for a guide to respond to various safety issues in the makerspace. Fifth, teachers suggested the need to increase the understanding of maker education among school members. If the understanding of maker education is low, it is difficult to use the makerspace and there may be problems with the safety of students. Teacher professional development support is required so that many teachers of various subjects can participate in maker education.

The recommendations for follow-up studies are as follows. First, this study was conducted for Korean national schools. Korean Schools consist of a system of national schools, public schools, and private schools. Depending on the type of school establishment, the application pattern of maker education, related budgets, and teachers' perceptions may vary. To accurately find out the actual situation of maker education, it is necessary to investigate through systematic sample design. Second, this study is limited to representing teachers in charge of maker education as it is aimed at teachers in charge of maker education. The form of maker education experienced by teachers in charge of maker education and general teachers may be different. It is necessary to find out what general teachers are worried about and the difficulties they face in preparing for maker education. Third, this study had limitations in examining the teaching and learning experience in detail as a fact-finding survey. This study had limitations in that it did not identify specific teaching and learning experiences and evaluation methods for maker education. It is necessary to qualitatively analyze the teaching experience that occurs in the design and implementation process of maker education and the learning experience experienced by learners. These studies will help to derive specific support strategies to support the field.

6. Conclusion

The purpose of this study is to investigate the status of maker education operation and consulting needs in Korean national schools. To this end, the research team operated the support group for the maker education, and conducted online and offline consulting, workshops, and surveys for maker education in all national schools (32 schools in total). The implications for supporting the implementation of maker education based on the research results are as follows. First, a systematic support system for maker education is required. As can be seen from the results of this study, teachers face many difficulties in building space, developing programs, and responding to safety issues. Space construction and safety issues often require professional knowledge beyond the teacher's experience and competency, so consulting by expert is essential. Teachers usually solve various problems by searching for information on the Internet or by asking acquaintances. Currently, the implementation of maker education depends only on the efforts and dedication of teachers, so difficulties may arise in the sustainable practice of maker education. The Ministry of Education and the Office of Education need to provide a pool of experts (architecture, safety, teaching and learning experts, etc.) and a pool of material resources that can provide timely consulting. Second, it is required to prepare a curriculum that can provide engineering experience through maker education. Although maker education can provide the practical and scientific experience required in engineering, the quality of maker education varies according to the interests and knowledge of teachers in the school field as there is no relevant content and system. Some students can gain various experiences in engineering, but most students encounter engineering as a simple experience. Methods to derive the core contents and functions of engineering education in elementary and secondary education and to implement them in connection with maker education according to the developmental level of students should be studied. Third, educational materials, tools, and equipment suitable for the developmental level of students should be developed and disseminated. Much of the equipment currently in the makerspace is made for adults in the industry. Schools do not have sufficient safety facilities and countermeasures as in the field, so field teachers have no choice but to worry about safety accidents in the implementation of maker education. Considering the curriculum of maker education and the level of student development, it is necessary to develop an educational engineering tool that can maximize the effect of making while ensuring safety.

Acknowledgements – The authors would appreciate the Korean Foundation for Advancement of Science and Creativity (KOFAC) and teachers in national school makerspaces. This research was conducted with the support of the KOFAC in 2021 and funded by the Ministry of Education in Republic of Korea.

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