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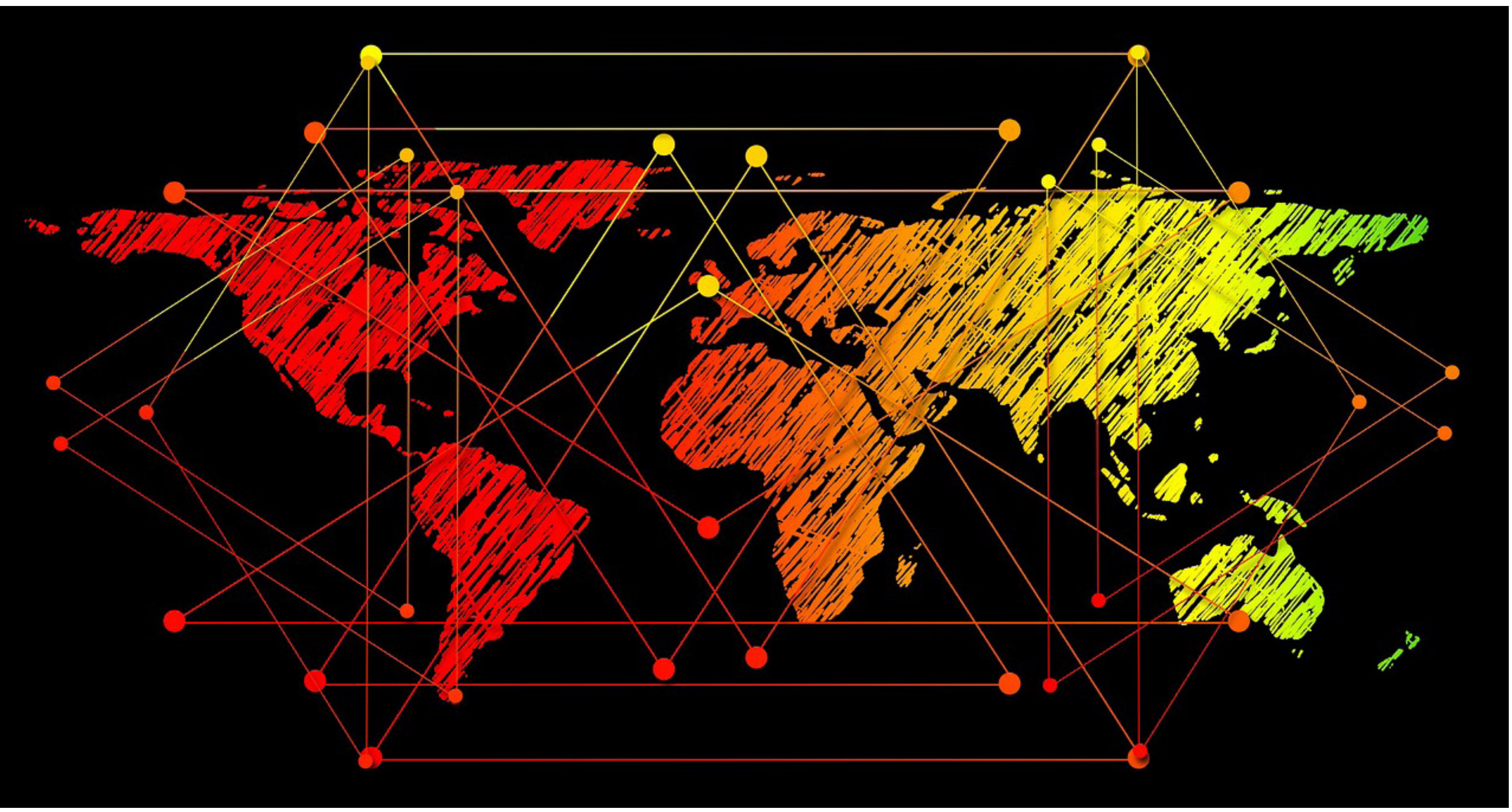
Connections and collaborative opportunities across countries, culture, and institutions.



March 7-9, 2024
Memphis, TN

A note from the ICTE 2024 Conference Chair

It has been an honor to oversee and interact with authors from around the world who have contributed to the ICTE 2024 conference proceedings. Relationships and interaction are the core of what we do professionally – without the impact we make on others, and the impact we feel from others, we are nothing. ICTE co-locating with ITEEA has been a unique and welcome opportunity to encourage, foster, and develop these important professional connections and we look forward to welcoming a range of delegates from across the globe.

Each of these papers represents important steps forward and across for our field; forward in terms of broadening our understanding and capacity to positively impact students, across in terms of connections and collaborative opportunities between countries, culture, and institutions. I extend my sincere gratitude to each of the authors and the team of reviewers who assisted in the vetting and improvement of each of these papers.

Sincerely,

Scott R. Bartholomew, PhD
ICTE Conference Chair, 2024

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Research Trends of K-12 Engineering Programs in the Republic of Korea

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Abstract

This study conducts a systematic literature review to explore the research trends of K-12 engineering programs in the Republic of Korea. The findings of this study provide a comprehensive overview of Korean K-12 engineering programs, including their key characteristics of the prior studies. The analysis framework included components such as publication year, data sources, grade level, curriculum subjects, research type, research outcomes, and teaching methods. First, it was found that research on K-12 engineering education programs is significantly lacking. Second, the majority of research on K-12 engineering education programs is from thesis and predominantly conducted in the curriculum subjects of middle schools and elementary schools. Third, quantitative research using a single-group pretest-posttest design is the most common research type. Fourth, there is active research on developing engineering education programs and validating their effectiveness. Fifth, STEAM and problem solving approaches were identified as the most commonly utilized teaching methods in K-12 engineering education. The findings give several implications to the field of technology education. First, further research is needed to validate the impacts of the developed engineering programs. Second, active research on engineering education focused on high school technology education is needed to improve the current situation of Korean high school technology education.

Key words: Engineering, Technology Education, K-12, Literature, Programs

1. Introduction

The development of engineering has brought revolutionary changes to human life. As the importance of engineering grows, the demand and need for engineering education in school education is also increasing (Choi et al., 2021). In response to these demands, research has been conducted on the development and implementation of engineering education programs for K-12 students (Kim et al., 2013; Kim et al., 2022; Lee, Y. & Lee, H., 2014). These studies revealed that students' creativity, engineering attitude, and problem-solving skills were improved by developing and applying an engineering education program suitable for school education.

In countries such as the United States, the United Kingdom, and Australia, engineering education has been strengthened in elementary and secondary education to secure national competitiveness and develop the country. The STEL (Standard for Technological and Engineering Literacy) was published in 2020 and it has been strengthened engineering education in technology education under the name ‘Technology and Engineering Education’ (Choi et al., 2021). The UK and Australia have traditionally practiced technology education in terms of engineering design by emphasizing problem solving and design processes in the technology education process (Kwon & Park, 2009). Meanwhile, in Korea, research and efforts has been made to secure connectivity with technology education and strengthen engineering content in South Korea (Lee, 2015; Choi et al., 2021). Starting with the organization of the ‘Engineering Technology’ subject in the 2007 revised curriculum, engineering education was conducted through the ‘General Engineering’ subject in the 2015 revised curriculum. Lim (2021) confirmed the engineering-centered change in countries such as the United States, the United Kingdom, and Australia through an international comparative study of high school technology and elective curriculum and emphasized the need for an engineering-centered shift in Korea's high school technology curriculum. Choi et al. (2021) announced that there are efforts and changes to reflect engineering in technology education in the United States and Japan, and argued that engineering needs to be emphasized in terms of the subject nature and goals of technology education in South Korea. In this trend, the technology area of the high school ‘technology/home economics’ curriculum of the 2022 revised curriculum consists of engineering-related content, which is the basis of engineering (Ministry of Education, 2022). Students are able to develop the basic knowledge and abilities required for a career in the engineering field, such as convergence engineering, engineering career exploration, engineering problem solving, creative design, invention and innovation, and practicing engineering ethics. Experiential activities, exploration of the world of various technologies and problem-solving activities in middle school courses are deepened with a focus on engineering, and cover innovation and convergence through basic engineering knowledge and cutting-edge engineering technology. As optional curricula, ‘Creative Engineering Design’, which is similar in nature to ‘General Engineering’ in the 2015 revised curriculum, and ‘Robots and Engineering World’, which focuses on robotics, were opened (Ministry of Education, 2022).

Despite the growing need and importance of engineering, it can be confirmed that awareness and education about engineering education are severely lacking in K-12 classrooms (Mo, 2022; Lee, 2015). Research on engineering education program development and effectiveness verification is still lacking (Mo, 2022). Therefore, in order to improve awareness of engineering education, research is needed to develop engineering education programs and verify their effectiveness. The purpose of this study is to identify research trends in engineering education programs in Korea, and the trends of this study will have several implications for future research in technology and engineering education.

2. Background

The value and effectiveness of engineering education have been proven through various studies. Engineering education programs help develop students' problem-solving skills (Kim, 2018) and improve students' self-efficacy (Lee, Y. & Lee, H., 2014). It has also been found to be effective in improving attitudes toward engineering, communication skills, and creativity (Jeong et al., 2014). In addition, engineering design, which is the core of engineering education, provides a way to connect technology education and engineering education, and classes using engineering design help motivate and improve students' achievement, and have a positive effect on cooperative learning and career education (Kwon & Park, 2009). Wicklein(2006) stated that engineering design elevated the field of technology education to a higher academic and technology level, providing an ideal framework for integrating mathematics, science, and technology, and that engineering provides students with an intensive education that can lead to a variety of career paths.

The value of engineering education can also be confirmed in the latest trends in technology education in the United States. Technology education in the United States changed from Industrial Arts or Technology Education to Technology and Engineering Education. In 2000, ITEA (International Technology Education Association) announced the Standard for Technological Literacy (STL) and presented content standards for technology education. The standard provides guidance to improve students' understanding of technology and technological systems and to support technological problem solving and innovation. The standards aimed to equip students with the knowledge and skills necessary to understand the technological world, acquire technological methods to solve technological problems, and make technological decisions in modern society.

Engineering education in Korea began mainly in high schools when ‘Engineering Technology’ was organized as an optional curriculum in the 2007 revised curriculum. The 'Engineering Technology' subject has the nature of a subject that encourages people to recognize that engineering is an essential element for maintaining and developing a rapidly changing modern society, and is taught by linking the technology areas of the 'Technology/Home Economics' subject from 7th to 10th grade. (Ministry of Education, 2011).

In the 2009 revised curriculum, 'Engineering Technology' was included as the subject name, linking it with the 'Technology/Home Economics' curriculum in middle school (7^{th} grade to 9^{th} grade) to cultivate the engineering knowledge needed in a knowledge-based industrial society and to foster creativity, practical problem-solving skills, and career development skills. In the 2015 revised curriculum, the ‘Engineering Technology’ subject disappeared and the ‘General Engineering’ subject was newly established. In the 2022 revised curriculum, the home-economics area of ‘Technology and Home-economics’ in high school (10^{th} grade to 12^{th} grade) was composed of the home science and the technology education area was composed of the engineering field, and engineering education in high school was strengthened. In addition, 'Creative Engineering Design' and 'General Intellectual Property', which are convergence elective subjects in the 2022 revised curriculum, and 'Robotics and Engineering World', which are career elective subjects, are the contents of elementary school 'Practical Arts' and middle school and high school 'Technology and Home-economics' subjects. The elective subjects of the 2015 revised curriculum are shown in Table 1, and the technology education elective subjects of the 2022 revised curriculum are shown in Table 2.

Table 1. Engineering Subject in Korean 2015 revised National Curriculum

Subject Name	Contents
General Engineering	Introduction of Engineering Engineering Literacy Engineering Problem Solving and Thinking Engineering and Intellectual Property Creative Engineering Design Creative Convergence Problem Solving World of Information and Communication Engineering World of Automation Engineering World of Material Engineering World of Energy Engineering World of Construction Engineering Convergence and Engineering IT based Convergence Engineering Bio based Convergence Engineering Prospect of Engineering Engineering Career Exploration

Table 2. Engineering Subjects in Korean 2022 revised National Curriculum

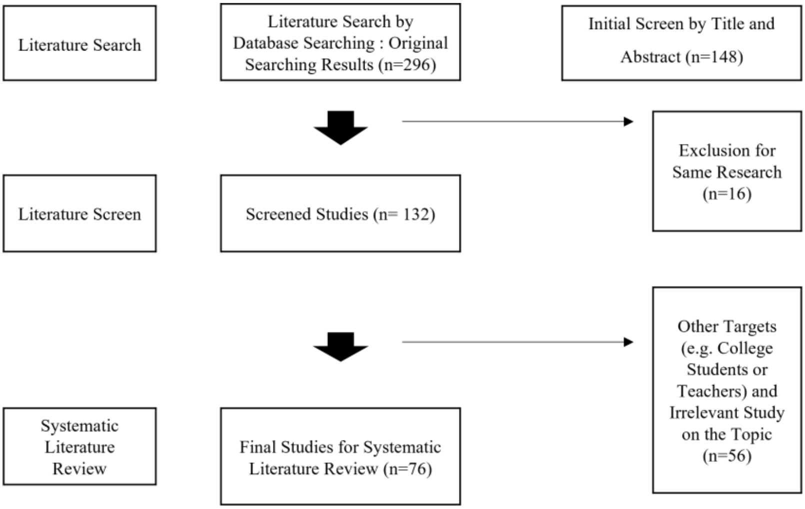
Subject Name	Contents

Robotics and Engineering World	It is a career elective subject for high school students from 10th grade to 12th grade, linking elementary school ‘Practical Arts’ and middle school ‘Technology/Home-economics’ subjects, and high school ‘Technology/Home-economics, creative engineering design, and general intellectual property’ subjects. This is a subject that considers interdisciplinary connections such as knowledge in various technology fields, technological problem-solving processes, and design and production activities. In particular, 'Robotics and Engineering World' utilizes basic knowledge in various subjects such as science, mathematics, and information to deepen and expand the content and level of technology, and to understand, design, and design robots, which are a representative example of the convergence of various technologies and engineering. This is a subject that provides an opportunity to solve robot-related problems while manufacturing and at the same time explore various career paths in the world of robot-related engineering.
Creative Engineering Design	It is a convergence elective subject for high school students from 10th grade to 12th grade, and is a subject that deepens and expands the contents and activities of 'Practical Arts' in elementary school and 'Technology/Home-Economics' in middle and high school and 'Robotics and Engineering World' in high school. This is a subject that horizontally connects and expands the contents and activities of 'General Intellectual Property' with 'Inventions', 'Technological Problem Solving', and 'Basic Areas of Engineering'. The 'Creative Engineering Design' course allows students to experience the problem-solving process of engineering, understand engineering, explore convergence engineering problems, and learn engineering problem-solving and creative design, which are the basic skills of engineering, to develop creativity and problem-solving abilities in the field of engineering.
General Intellectual Property	It is a convergence elective subject for high school students from 10th grade to 12th grade, covering the areas of invention, technological problem solving, and creative engineering in elementary school 'Practical Arts', middle school 'Technology/Home-economics', and high school 'Technology/Home economics, creative engineering design'. This course deepens and expands the design area in terms of content and level, providing basic knowledge understanding and experiential learning opportunities for intellectual property rights, and providing students with the ability to create, protect, and utilize intellectual property rights based on creative and convergent thinking. .'General Intellectual Property' is a subject designed to explore practical and interesting cases related to inventions and intellectual property, solve problems, and explore career paths in intellectual property-related fields through intellectual property project activities.

3. Research Design

This study is a systematic literature review study to identify trends in previous studies related to engineering education programs targeting K-12 students in the Republic of Korea. The overall flow of the research is as shown in Figure 1.

Figure 1. Literature Selection Process Flowchart



3.1. Data Collection

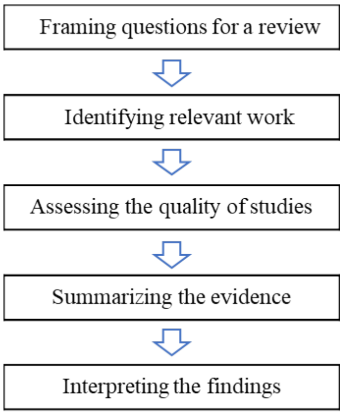
To analyze the research trends of engineering education programs, theses and academic journals on engineering education programs for K-12 students from 2007 to 2023 were analyzed. Data searches were conducted using Korea's representative academic databases, RISS, DBpia, and Google Scholar. Keywords for data search include ‘engineering’, ‘engineering education’, ‘technology education’, ‘program development’, ‘effect’, ‘impact’, ‘STEAM’, ‘topic selection program’, ‘problem solving’, ‘Engineering education’ ', 'Innovations in engineering education', 'Technology integration in engineering education', 'Engineering curriculum design', and 'Engineering education research' were used to search for data.

A total of 1789 papers were collected as a result of the primary literature search by combining key words. Among the papers initially collected, a total of 148 papers were selected based on the Korean abstracts, excluding papers that did not mention engineering or were not related to engineering education. The thesis selection process was finalized through a data review meeting consisting of one doctorate in the field of technology education and two technology teachers. In this process, 90% agreement was achieved through the review and judgment of all members, and in cases where opinions differed, differences were reconciled through discussion, and only the papers that reached consensus were ultimately selected for literature analysis. From all papers, 16 overlapping studies were excluded by determining whether there was overlap between thesis and academic journals. Afterwards, 76 papers were selected for systematic literature review by excluding papers where the research subjects were university students and 56 papers whose topics were not related to the engineering education program.

3.2. Systematic Literature Review

The systematic literature review procedure to identify research trends in engineering education programs was conducted according to the five steps of Khan et al (2003), as shown in Figure 2.

Figure 2. Systematic Literature Review Process



The topic of this study is to identify research trends in engineering education programs. Research trends in engineering education programs can be identified and the direction of research on engineering education in technology education can be recommended. This study selected a total of 148 papers by searching theses and various academic journals using Korea's representative academic databases, RISS, DBpia, and Google Scholar. Among the 148 papers selected through the literature search, a total of 76 papers were selected for analysis by excluding from the analysis subjects those that overlapped with degree theses and academic journals, papers targeting college students, and papers not related to engineering education.

To extract data, the analysis framework shown in Figure 3 was created by referring to the analysis frameworks of Lee (2019) and Ahn (2022), and the selected papers were analyzed using the analysis framework. The papers for the analysis were divided by publication year, data source, school level, and subject status to identify overall research trends. Depending on the type of study, it was divided into quantitative research, qualitative research, mixed research, and conceptual research, and the specific research methods were analyzed by dividing them into experimental control group quasi-experimental design, single-group quasi-experimental design, survey, interviews and observations, and meta-analysis.

Figure 3. Analysis Framework (Content Analysis Table)

Year	Publication Year
Data Source	·Journal Paper ·Theses
School Grade	·Kindergarten ·Elementary School ·Middle School ·High School
School Subject	·Curriculum Subject ·Non-Curricular Activities
Research Type I	·Quantitative ·Qualitative ·Mixed
Research Type II	·Experimental Control Group Quasi Experimental Design ·Survey ·Single School Quasi Experimental Design ·Interview and Observation
Research Outcomes	·Program Development ·Develop and Implementation ·Program Implementation and Effects ·Implementation
Teaching Methods	·STEAM ·Invention · Maker ·Problem Solving ·Hands-on Activities ·Others

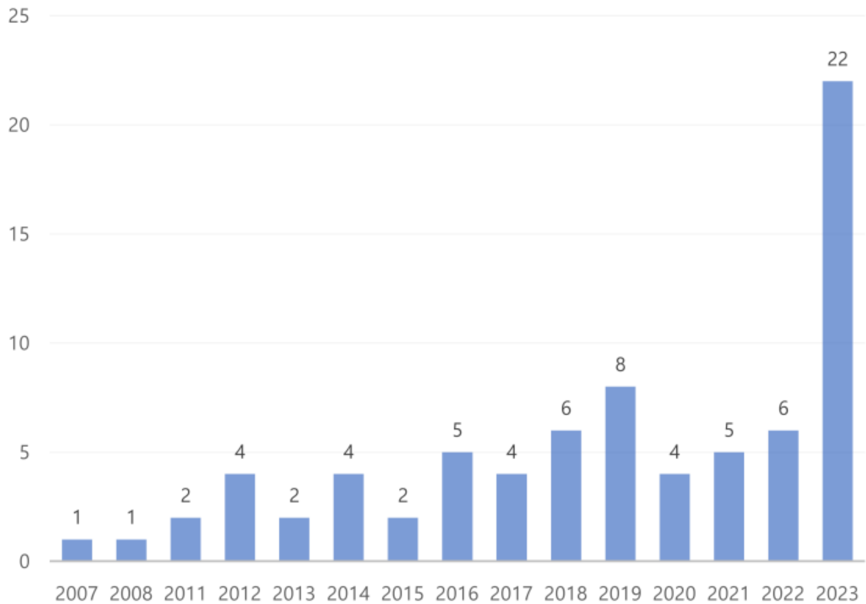
In this study, the research trends of engineering education programs were identified for each component of the content analysis framework. This study can suggest a direction in which engineering education program research should complement and move forward.

4. Research Trends of Engineering Education Program

4.1. Year of Publication

Research papers related to engineering education programs were identified by year. The papers selected for analysis are distributed from 2007 to 2023 (See Figure 4). Starting in 2007, Korea's engineering education was considered to have started focusing on high schools as the 'Engineering Technology' subject was organized as a selective curriculum subject in the 2007 revised curriculum. This trend indicated the years in which research was actively conducted, with 22 papers in 2023, 8 papers in 2019, and 6 papers in 2018. In particular, it was confirmed that research related to robots and artificial intelligence will increase noticeably in 2023, reflecting social interest.

Figure 4. Studies by publication year



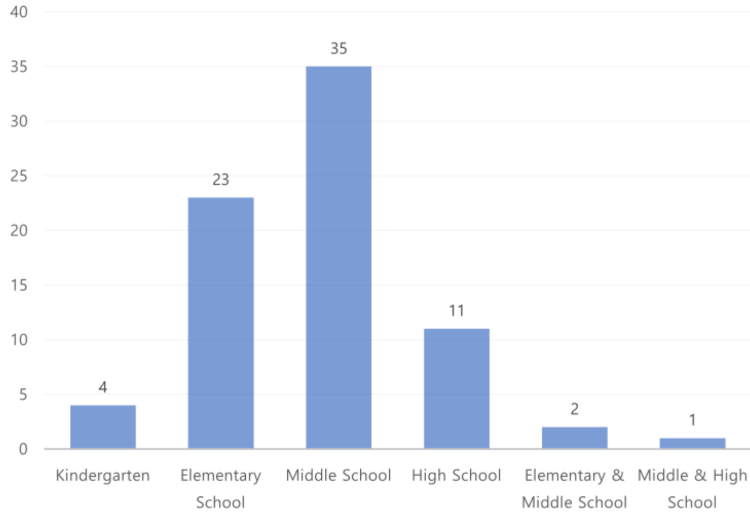
4.2. Data Source

As a result of dividing the published papers into academic journals and theses, it was determined that there were 26 academic journals and 50 theses. In cases where academic journals and dissertations covered the same topic, they were classified as academic journals and analyzed. It can be seen that research related to engineering education programs has been conducted more actively, focusing on degree theses.

4.3. School Grade of the Participants

The school grade for the participants was analyzed by dividing it into kindergarten, elementary school, middle school, and high school (See Figure 5). The school grade with the most active research is middle school (35 papers), followed by elementary school (23 papers), high school (11 papers), and kindergarten (4 papers). There were two papers that covered both elementary and middle schools, and one paper that covered both middle and high schools. It was confirmed that more effective education would be possible if connected engineering education was provided in elementary and middle schools, where most of the research was conducted. In addition, it indicates the reality that research on engineering education is significantly lacking in high schools that emphasize and include engineering subjects.

Figure 5. Studies by School Grade



4.4. School Subject

The analysis was divided into curricular and non-curricular subjects depending on whether or not they were included in the curricular hours of the school's regular curriculum. There are 61 papers related to the school subjects, 14 papers related to the subject, and 1 paper related to both, which confirms that research on engineering education programs centered on the subject is becoming more active. In particular, the subjects in which engineering education is mainly conducted are Practical Arts in elementary schools and Technology/Home-economics in middle and high schools, and it was confirmed that engineering education is centered on technology education in school curriculum.

4.5. Research Type I

Research types were analyzed by dividing them into quantitative research, qualitative research, and mixed research. Of the total 76 related papers, 74 were quantitative research studies, and there was 1 each of qualitative and mixed research studies. Most engineering education program-related studies related to program development and program application effects can be interpreted as taking the form of quantitative research appropriate for the development, implementation, and effectiveness verification of the program.

4.6. Research Type II

As a result of analyzing research type I in detail, it was found to be 2 observation and interview, 60 single-group quasi-experimental designs, 12 experimental control group quasi-experimental designs, and 2 survey.

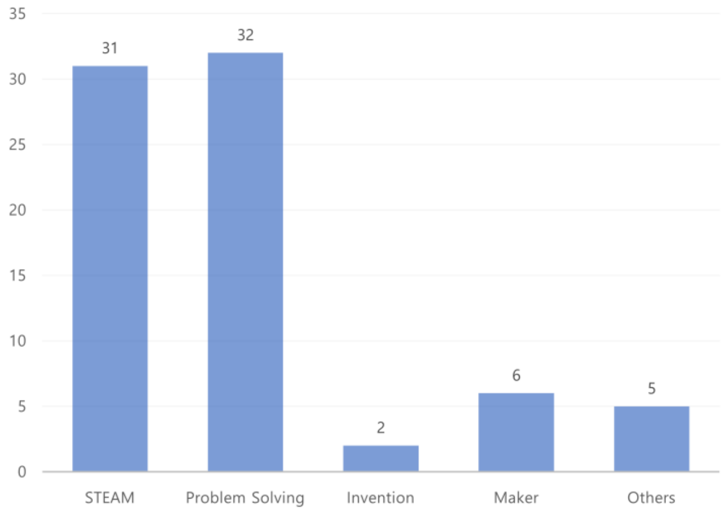
4.7. Research Outcomes

As a result of analyzing the research results of engineering education program-related studies by type, one study observed changes in participants' perception, two studies developed a model, one study developed a model and verified its effectiveness, and one study developed a program. There were 50 studies that developed programs and verified their effectiveness. But, other studies had program or instructional materials.

4.8. Teaching Methods

As a result of analyzing the teaching methods applied to the engineering education program research, 31 studies were STEAM, 32 articles were problem solving, and 6 articles were maker education (See Figure 6). It was confirmed that the most appropriate method for applying engineering education in school settings is to mainly apply engineering education through STEAM education and problem-solving methods that include the engineering design process, which is the core of engineering education.

Figure 6. Studies by Teaching Methods



5. Summary & Discussion

As a result of a systematic literature review, as of 2007, approximately 5 papers related to engineering education programs have been published every year, and unlike other years, 2023 is characterized by an explosive increase in papers related to artificial intelligence and robots. Looking at the results according to data source, it can be seen that research on engineering education programs is being conducted more actively, focusing on theses. Depending on the school level, the order was middle school, elementary school, high school, and kindergarten, and most research has been conducted in middle school and elementary school. Depending on whether it is a subject or not, it was confirmed that subjects are being conducted much more actively than subjects other than subjects, and that engineering education program research is being actively conducted, especially focusing on technology education. Depending on the type of study, it was confirmed that most studies were in the form of quantitative research and were mainly single-group quasi-experimental designs. According to the research results, most of the research on engineering education programs took the form of research to develop programs and verify their effectiveness. According to teaching methods, papers mainly focus on STEAM and problem-solving methods, and engineering elements mainly focus on designs suitable for the engineering problem-solving process.

6. Conclusion & Recommendations

This study conducted a systematic literature review to investigate research trends in Korean K-12 engineering education. The main conclusions of this study are as follows.

First, although research on engineering education programs has been conducted consistently every year since 2007, the number of studies was confirmed to be very insufficient. Therefore, more research is needed to inform the effectiveness of engineering education programs. In addition, it can be seen that the number of studies conducted every year, which was less than 10, has rapidly increased to 22 in 2023, and most of the papers were papers using artificial intelligence. The reason why so many research topics are artificial intelligence can be interpreted as a result of social interest and importance of artificial intelligence in engineering education, and is related to the fact that graduates from artificial intelligence convergence graduate schools have recently begun to be produced.

Second, research on engineering education programs is focused on elementary and middle schools, and it can be confirmed that there is a lack of research in kindergartens and high schools. Through this, connected engineering education is needed, starting from kindergarten and elementary school, where engineering education has a large effect, all the way to high school. Additionally, the need for more active research on high school students was confirmed. In order to overcome the educational environment centered on entrance exams and to provide effective engineering education in high schools, research is needed to inform the importance and necessity of engineering education in high schools.

Third, research on engineering education programs is more active focusing on curricular subjects. In particular, it can be confirmed that engineering education is centered on Practical Arts in elementary schools and technology subjects in middle and high schools, and it has been confirmed that engineering education centered on technology education in school education is effective.

Fourth, as a result of analysis based on teaching methods, research on engineering education programs through STEAM and problem-solving methods is being conducted most actively. This confirmed that convergence and problem solving, which is the core of engineering education, are effectively reflected in the engineering education program. In addition, in terms of engineering elements, research emphasizing design is actively being conducted, confirming that the engineering problem-solving process is being emphasized. However, the number of studies on engineering education through maker education is insufficient, and it was confirmed that more research on engineering education centered on maker education is needed.

Based on the research results, suggestions for follow-up research are as follows.

First, research is needed to verify the effectiveness of the developed engineering education program. Because much research ends with the development of a program, the educational effects of applying the program are not verified, making it difficult to apply the program in school settings. If the effectiveness of the developed engineering education program is actively verified, it will be of great help in spreading the engineering education program.

Second, research and development of engineering education programs on various topics are needed. Due to the nature of engineering education, although it can cover a wide variety of topics, it was confirmed that the topics were very limited and that research related to specific topics was concentrated in specific years. In particular, by 2023, most research will be on artificial intelligence. For the development of engineering education, research on more diverse engineering fields is needed.

Third, active research on engineering education focusing on technology education in high schools is needed. Although technology education emphasizes engineering education in high schools, research on engineering education through technology education in high schools is still lacking.

Fourth, training and education are needed to enhance technology teachers' expertise in engineering education. Technology education experts in charge of technology education in schools are insisting on emphasizing engineering education in technology education. However, there is a need to increase expertise in engineering education, and there is a lack of materials and programs that can be applied in schools. Therefore, in order to successfully spread engineering education in schools, support for technology teachers in charge of engineering education is urgently needed.

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Learning Models of STEAM Education in Japan: Through the Project of Hyogo University of Teacher Education

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Abstract

The purpose of this research is to create a practical model for STEAM education in Japan through the project of Hyogo University of Teacher Education. Japan has lagged other countries in the field of STEAM education. However, since 2018, Government of Japan has started to pay attention to STEAM education as transdisciplinary learning that combines STEM (sciences, technology, engineering, and mathematics) and Arts (including humanities). Currently, STEAM education has not been formally incorporated into Japan's national curricula, but there is a high possibility that it will be adopted in next revision of national curricula. The Hyogo University of Teacher Education (HUTE) has been designated as "the Flagship University for Teacher Training Program" by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). As part of this designation, the university has decided to develop practical learning model of STEAM Education. Firstly, we conducted a survey on Japanese teachers and university students' awareness to STEAM education. As a result, it was suggested that university students may not have sufficient awareness for STEAM education, because they did not experience it themselves during their student days. From this, it was indicated that it is important to provide opportunities for university students to experience the benefits of STEAM education for themselves. So, we attempted to implement STEAM education for the university students, and developed learning models based on this trial. Finally, three models such as "Seeds Application STEAM Model", "Bridging Exploration STEAM Model" and "Integrative STEAM Model" were developed, and discussed how to implement the developed learning models into school curriculum.

Key Words: STEAM Education, Learning Model, Japan, Hyogo University of Teacher Education, the Flagship University for Teacher Training Program

1. Introduction

1.1 Purpose of the Study

The purpose of this study is to propose practical models for STEAM education in Japan, through the trial practices in Hyogo University of Teacher Education implemented as the project of "The Flagship University for Teacher Training Program."

1.2 Background

Trends on STEAM Education in Japan

Currently, STEM/STEAM education practices are being actively implemented worldwide. However, in Japan, STEM/STEAM education has not always been given significant emphasis. Attention to STEAM education in Japan began around 2018. Discussions on the implementation of STEAM education in Japan began in the “Ministerial Meeting on Human Resource Development for Society 5.0” (the Task Force in the Ministry) at the Ministry of Education, Culture, Sports, Science and Technology (MEXT 2018a). Society 5.0 refers to a concept that the Japanese government aims to achieve, which represents a new type of society (Cabinet Office, 2016). Society 1.0 represents the hunting society, 2.0 represents the agricultural society, 3.0 represents the industrial society, and 4.0 represents the information society. Society 5.0 envisions a society where Society 1.0 to 3.0 are highly integrated with Society 4.0, aiming for sustainable development and the resolution of social challenges.

The Task force's report discusses the desired profile of human resources and the approach to learning needed to achieve Society 5.0. In this context, it pointed out that in senior high schools, "many students tend to be divided into "Arts and humanities" or "STEM" tracks from the second grade (17 years old) onward, and they do not adequately learn some subjects in the other track." And the report suggests, "It is necessary for all students to learn STEAM education as a foundation of thinking." In other words, the focus on STEAM education in Japan began with concerns about the division between Arts and STEM, and with the goal of developing the workforce needed to realize Society 5.0. Subsequently, various documents have highlighted the importance of STEAM education in Japan. In this context, discussions about STEAM education are being driven by two ministries: the MEXT and the METI (Ministry of Economy, Trade, and Industry) (MEXT 2018a, 2019, 2021a, 2021b, 2021c, 2022, 2023a, METI 2019, 2022, 2021, Cabinet Office 2019).

Each ministry has a slightly different definition of STEAM education. MEXT defines STEAM education as "transdisciplinary education that applies learning in various subjects to solving real-world problems." Additionally, it defines the scope of the 'A' in STEAM to encompass a broad range, including not only fine art and culture but also aspects of daily life, economics, law, politics, ethics, and more (Liberal Arts). On the other hand, METI refers to STEAM education as "STEAMification of learning" (METI 2020). The meaning of this coined word is explained as the realization of a learning process where all students awaken a sense of excitement, regardless of whether it is related to STEM or Arts. And it is proposed as cyclical learning that involves both "knowing," which involves acquiring subject knowledge, and "creating," which involves thinking creatively, logically, and finding solutions to unknown challenges through project-based learning (PBL). The difference in the definition of STEAM education between METI and MEXT lies in the different responsibilities that the ministries have; METI sees STEAM education from the perspective of developing human resources to promote economic activity. MEXT, on the other hand, sees all students in all schools as benefiting from STEAM education; MEXT is a little more cautious. Nevertheless, at the G7 Education Ministers' Meeting held in Japan in 2023, it was stated that " promote a broad and balanced interdisciplinary education such as STEAM education for all students, and develop learners' skills in growth fields such as digital and green technologies and fostering entrepreneurship" (MEXT 2023b). The research and practice of STEAM education in Japan is expected to accelerate today and in the near future by MEXT.

Until now, Japan's national curriculum has "the period of Integrated Studies" that aims to explore authentic issues in daily life and society by applying learning from various subjects (MEXT 2017a). However, there are no textbooks or completed curriculum for "the period of Integrated Studies." Each school must devise and implement its own. So, Both MEXT and METI see the possibility that STEAM education can be implemented in "the period of Integrated Studies." For this, it has been considered that incorporating "creation" with design thinking, within the previously inquiry-focused "the period of Integrated Studies" is important. For the design thinking, the 5 Steps model (Empathize, Define, Ideate, Prototype, and Test) proposed by Stanford University's "d.school" is well introduced in Japan (YOSHIHARA & KIJIMA 2019), Institute of Design at Stanford 2012).

Based on the above trends of discussion, the concept of STEAM education in Japan can be summarized into the following seven points:
A. Transdisciplinary learning that integrates STEM and Arts.
B. Learning that engages students in real-world problem solving.
C. Curriculum management that focuses on the "Period of Integrated Studies" and promotes collaboration across various subject areas.
D. Project-based learning.
E. Learning cycle of inquiry and creation.
F. Incorporating design thinking including prototyping.
G. Valuing individual excitement in the challenge or warm heart to users/personas.

Issues and constraints on STEAM education in Japan

However, there are several issues and constraints on implementation of STEAM education in Japan. Firstly, one of the constraints is the presence of robust national curriculum, with textbooks approved by the MEXT being used. The current national curriculum, revised in 2017-2018, does not incorporate the concepts of STEAM education since discussions on STEAM education began in 2018 (MEXT 2017b, 2017c, 2018b). Consequently, in the current school environment, there is no imperative to practice STEAM education since it is not prescribed in the national curriculum. In Japan, mathematics remains distinct as mathematics, and science remains distinct as science, and it is not possible to incorporate elements from multiple subjects into a single class. It is considered that there is a need to develop an appropriate learning model for STEAM education that can be implemented within the framework of current national curriculum.

Secondly, one of the issues in Japan is there is often a strong sense of specialization within each subject, and fostering collaboration among various subject teachers is not always easy, especially in junior and senior high school. In Japan, teaching licenses for elementary school permit to teach all subjects, while licenses for junior and senior high school teachers are subject-specific. To implement STEAM education effectively in junior and senior high schools, collaboration among teachers with diverse subject expertise is necessary.

Thirdly, there is an inadequacy in the framework for subjects responsible for technology & engineering within STEAM education. In terms of learning about digital technology, Computing Education (referred to as Programming Education in Japan) has been introduced across subjects at the elementary school level. Junior high schools have a subject called "Technology," and senior high schools have "Informatics" as a subject. However, when it comes to learning opportunities related to physical technologies such as materials and its processing, electrical/electronic, mechanical, and biological technologies, these are primarily covered under only the junior high school subject "Technology," with no equivalent subjects in elementary or senior high schools. Furthermore, unlike the United States' NGSS (Next Generation Science Standards 2013), Japanese science education does not include elements of engineering practice and is limited to natural sciences. As a result, much of the recent experimental STEAM education practices in Japan have been skewed towards the application of digital technology, such as programming, with limited exposure to physical technologies. Based on these issues and constraints, there is a need to construct a Japan-style STEAM education that can be implemented within the conditions of Japan's national curriculum.

1.3 Research Approach

During this movement, Hyogo University of Teacher Education, where the authors are affiliated, has been designated by the MEXT as "the Flagship University for Teacher Training Program." "The Flagship University for Teacher Training Program" is an initiative where the MEXT designates universities to play a leading role in transforming the teacher training system. This program, initiated in 2022, currently involves the designation of four universities nationwide, with Hyogo University of Teacher Education being one of them. Our university's plan, called as the "TEX Program" (Teacher Education Program for the Transformation), encompasses five themes. One of these themes is the development of a learning model for STEAM education and its implementation in teacher training program (HUTE 2022). In this paper, we will introduce results of the project aimed at constructing a STEAM education learning model undertaken by Hyogo University of Teacher Education.

2. Methods

2.1 Survey on Awareness of Teachers and Students to STEAM Education

At the beginning of the project, we conducted a survey to assess the awareness of university students and teachers regarding STEAM education. For this, we got the support of the MEXT's "Integrated Reform Promotion Project for Teacher Training, Recruitment, and Training" (MEXT 2021d). The subjects were a total of 1,746 participant, consisting of 1,216 teachers (elementary, junior, and Senior high school teachers), 122 supervisors of board of education, and 397 university students (undergraduate). The questionnaire included three questions about awareness toward the concept of Society 5.0 and eight questions related to confidence of practicing STEAM education. The response format was a 5-point Likert scale. Incidentally, we didn't give subjects any information about Society 5.0 or STEAM education prior to the survey. This is because we wanted to understand the subjects' awareness of Society 5.0 and STEAM education that was formed in their daily lives.

2.2. Development of Learning Models of STEAM Education

Based on the result of survey, we attempted to develop a curriculum for STEAM education in teacher training program. We set up Development Team for STEAM Education within the university and organized three sub-teams, combining teachers from STEM field with teachers from Arts field. Each sub-team tried to develop practicable STEAM education, and to implement it on university students. After trial practices, we then reflected, discussed, and modelled the results of the practices.

3. Result and Discussion

3.1 Awareness of Teachers and Students to STEAM Education

The results of the survey regarding the consciousness toward the concept of Society 5.0 are shown in Table 1. Regarding the item "I understand the concept of Society 5.0," supervisors' Mean score and its 95%CI exceeded the neutral point of 3.00 on the 5-point scale, while university students and teachers scored below it. It is suggested that the awareness of the Society 5.0 among university students and teachers is not so high. However, for the items "I think realizing Society 5.0 is important for the future of Japan" and "School education plays an important role in realizing Society 5.0," both university students, teachers, and supervisors scored above the neutral point. This suggests that supervisors understand the importance of Society 5.0 and the role of educational reform towards its realization. However, this is contradictory. It is suggested that university students and teachers may have a vague understanding of the concept of Society 5.0 and its importance, as well as the necessity for educational reform to achieve it. In other words, it is expected that university students and teachers do not have a correct understanding of Society 5.0, but only have an image that it is important because they often hear this term in the media and newspapers. Furthermore, in all items, positive responses were highest among supervisors and lowest among university students. This suggests the need for Japan's teacher training programs to ensure that university students have a solid understanding of the new social vision and role of education for it.

Next, the results regarding confidence in instruction of STEAM education is shown in Table 2. Supervisors, with a few exceptions, have mean scores and their 95%CI higher than the neutral point of 3.00, indicating that they have confidence in practice of STEAM education. However, teachers and university students have Mean scores and their 95%CI below the neutral point in almost all items, suggesting a lack of confidence in practicing STEAM education. Particularly, the Mean scores for "Implementing inquiry/creativity-centred PBL," "Facilitating PBL," and "Collaborating with companies and local community" are low, indicating anxiety about implementing community-engaged PBL. Also, mean scores and their 95%CI for items related to setting themes, such as "Setting themes including both STEAM and Arts," were also lower than the neutral point of 3.00. On the other hand, the response to "Collaborating with colleague teachers with different specializations" was moderate for teachers but remained low for university students.

Table 1.
Consciousness toward the concept of Society 5.0

Items	Group	*Mean*	*S.D.*	*Med.*	*95%CI*
"I understand the concept of Society 5.0"	University students	2.44	1.35	2	[2.31-2.57]
	Teachers	2.78	1.38	3	[2.70-2.86]
	Supervisors	4.19	0.77	4	[4.06-4.32]
"I think realizing Society 5.0 is important for the future of Japan"	University students	3.92	0.85	4	[3.84-4.00]
	Teachers	3.50	1.01	4	[3.44-3.56]
	Supervisors	4.38	0.76	5	[4.25-4.51]
" I think School education plays an important role in realizing Society 5.0"	University students	3.93	0.88	4	[3.84-4.02]
	Teachers	3.46	1.00	3	[3.40-3.52]
	Supervisors	4.37	0.76	5	[4.24-4.50]

Note: university student *n*=397, teachers *n*=1216, supervisors *n*=133

Table 2.
Confidence of practicing STEAM education

Items	Group	*Mean*	*S.D.*	*Med.*	*95%CI*
"Understanding the concept of STEAM education"	University students	2.61	1.30	2	[2.48-2.74]
	Teachers	2.47	1.11	2	[2.41-2.53]
	Supervisors	3.38	1.08	4	[3.19-3.56]
"Setting trans- or interdisciplinary themes"	University students	2.44	1.21	2	[2.32-2.56]
	Teachers	2.98	1.12	3	[2.92-3.04]
	Supervisors	3.50	1.01	4	[3.33-3.67]
"Setting themes including both STEAM and Arts"	University students	2.29	1.16	2	[2.18-2.40]
	Teachers	2.56	1.05	2.5	[2.50-2.62]
	Supervisors	3.16	1.06	3	[2.98-3.34]
"Setting themes related problem-solving in the real world"	University students	2.50	1.12	3	[2.39-2.61]
	Teachers	2.93	1.10	3	[2.89-2.99]
	Supervisors	3.42	1.03	4	[3.24-3.59]
"Implementing inquiry/creativity-centered PBL"	University students	2.07	1.13	2	[1.96-2.18]
	Teachers	2.38	1.08	2	[2.32-2.44]
	Supervisors	2.98	1.13	3	[2.79-3.17]
"Facilitating PBL"	University students	1.76	0.96	1	[1.67-1.85]
	Teachers	2.07	0.98	2	[2.01-2.13]
	Supervisors	2.77	1.18	3	[2.57-2.97]
"Collaborating with colleague teachers with different specializations"	University students	2.24	1.22	2	[2.12-2.36]
	Teachers	3.30	1.12	4	[3.24-3.36]
	Supervisors	3.66	1.07	4	[3.48-3.84]
"Collaborating with companies and local community"	University students	2.16	1.19	2	[2.04-2.28]
	Teachers	2.61	1.15	2	[2.55-2.67]
	Supervisors	3.34	1.15	4	[3.14-3.54]

Note: university student *n*=397, teachers *n*=1216, supervisors *n*=133

From these results, when we focused on university students, two points can be pointed out. First, university students may not have sufficient awareness for STEAM education, because they did not experience it themselves during their elementary, junior, and senior high school. It is predicted that this may be causing concerns about teaching in PBL and setting themes related to STEAM. Second, in Japan's teacher training programs, where many obtain teaching licenses through subject-specific courses, there may be inadequate opportunities for collaboration with others who have different specializations. In other words, to promote STEAM education in Japan, it is believed that reforming teacher training programs is necessary, and within the programs, it is important to provide opportunities for university students to experience the benefits of STEAM education themselves and to collaborate with different specializations on PBL projects.

3.2. Trial Practices of STEAM Education in HUTE

At Hyogo University of Teacher Education, a project was initiated in 2021 to launch new course subjects related to STEAM education in the teacher training curriculum. Taking into consideration the survey results, the concept was conceived to offer a lecture titled "Introduction to STEAM Education" to help students understand the concepts and practical strategies of STEAM education. Additionally, an exercise titled "STEAM Education Practicum" was planned to allow students to engage in STEAM Project. Under this concept, trial practices were conducted within some of the existing course subjects in the current curriculum (NAGAT et.al 2022). Trial practices in "STEAM Education Practicum" in 2022 were as follows:

Practice 1: STEAM Education Focusing on Understanding STEM seeds and applying them for Inquiry and Creation in Arts.
Using text mining technology, students analysed the characteristics of Japanese haiku by poets such as Matsuo Basho and Kobayashi Issa. Students conducted research on materials related to haikus by Matsuo Basho and Kobayashi Issa and formulated hypotheses about the features of their haikus. Subsequently, they used text mining to verify the hypotheses they had formulated.

Practice 2: STEAM Education Emphasizing Inquiry and Creation while Deepening Questions on cross- curricular theme
The theme centred on the concept of "beauty" shared by mathematics and fine art, specifically focusing on "Mandala String Art." Students explored the mathematical rules underlying Mandala String Art through computer programming. After that, they tried to design original artwork by programming and carried out its fabrication. Finally, the students considered the intellectual property protection of designs created by computer, prompted by a lecture from an external speaker (art designer).

Practice 3: Inquiry and Creation in STEAM Education with a Comprehensive Theme
Students explored and engaged in real-life problem-solving based on their interests among the 17 goals of the SDGs. The lessons followed 5Steps thinking process. Students focused on the issue of plastic waste and their desire to address it. First, they conducted research on this issue using various resources. Afterward, they set a goal to raise awareness about this problem in various people in the university. They then developed bamboo lunchboxes as an alternative to the plastic ones used in the university cafeteria and sold them along with pamphlets to educate people.

3.3. Development of Learning Models for STEAM Education

The themes of haiku, Mandala String Art, and SDGs are consciously designed to bridge STEM and Arts. In the practice, it is considered essential to establish appropriate themes that incorporate elements from both STEM and Arts. However, the strategies for implementation can vary depending on the context. The differences in these approaches can be illustrated as shown in Figure 1.

Practice 1 tried to make bridge between STEM and Arts by initially establishing learning about STEM seeds like text mining using NLP (Natural Language Processing), and subsequently applying it to literary works like Haiku. As different examples of this approach include, for instance, after learning about digital fabrication as technological seeds, students research what is needed within the school and create prototypes by 3D-Printer, and so on. So, we named this approach as "Seeds Application STEAM Model." In *Practice 2*, the theme is set as "Mandala String Art" because it can be designed with elements of both mathematics and fine art. However, this alone may not naturally establish connections with technology and engineering or humanities. Therefore, by using students' questions as a starting point and deepening exploration, learning is gradually designed to incorporate cross-disciplinary elements, such as simulating design through programming and discussions on the rise of "Mandala String Art" as a culture. So, we named this approach as "Bridging Exploration STEAM Model." In *Practice 3*, a wide gateway for exploration is established by setting the theme such as SDGs. In this approach, students are required to integrate knowledge and skills related STEM and Arts by themselves. However, there is a concern that with such a broad theme, students' exploration may lean towards either STEM or Arts. Therefore, teachers closely monitor students' inquiries and provide guidance, hints, and samples as needed to facilitate transdisciplinary exploration between STEM and Arts. This is a STEAM education model where challenges are identified and tasks are set from a socially relevant theme. So, we named this approach as " Integrative STEAM Model."

When implementing the third model as STEAM education in elementary, junior, and senior high schools, it can be practiced during the "Period of Integrated Studies." Therefore, we developed detailed strategy that incorporates design thinking into the exploration process during "Period of Integrated Studies," as shown in Figure 2 (Moriyama, et.al 2022). The first half learning cycle involves the process of exploration, where students set tasks, gather information, and analyse them. After that, they find specific users or personas and engage in creation activities through design thinking. Design thinking involves the processes of Empathize, Define, Ideate, Prototype, and Test, and through this learning cycle, students reach to propose solutions to the users. Like this way, our project proposed three types of model and detailed strategies as learning models of Japan-Style STEAM education.

Figure 1.
Three types of Learning Model for STEAM Education proposed by HUTE

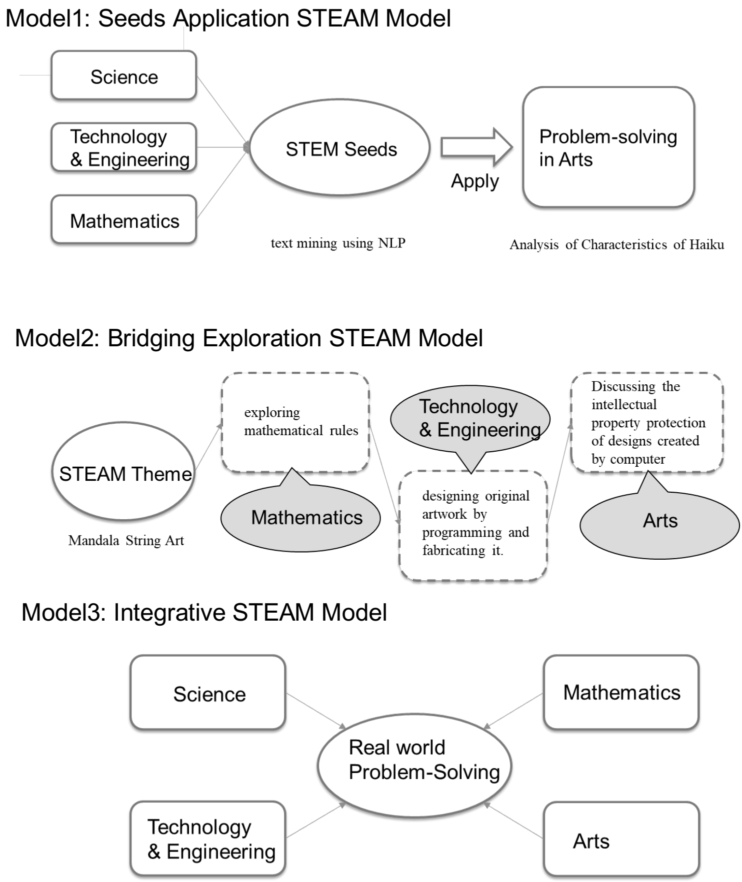
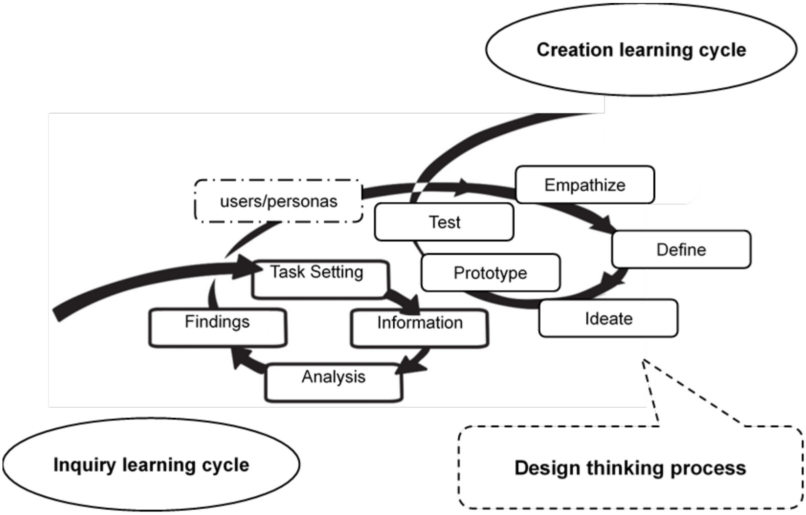


Figure 2.
Detailed Learning Processes of Integrative STEAM Model



3.4 Discussion

In this section, we discuss how to implement the developed learning models into the school curriculum. As mentioned earlier, STEAM education in Japan had conditions A to G (refer to Section 1.2). We examine the compatibility of the three developed learning models with these seven conditions. All learning models integrate STEM and Arts, thus these are complied with Condition A. Also, since all learning models involve learners addressing real-world problem-solving, they also meet Condition B. Similarly, as all learning models embrace Project-based learning, and have both activity of inquiry and creation, prioritizing individual excitement, it is considered that they align with Conditions D, E, and G.

However, there are differing evaluation regarding Conditions C and F. "Integrative STEAM Model" anticipates the implementation of "the Period of Integrated Study," aligning with Condition C. In contrast, "Seeds Application STEAM Model" places priority on the learning of technological seeds, the role of technology and engineering education particularly important. Implementing "Seeds Application STEAM Model" ahead of other models allows learners to acquire technological knowledge and skills, and engineering problem-solving abilities. On the other hand, "Bridging Exploration STEAM Model" involves a certain degree of guide by teachers, with STEM and Arts elements switching within a single project. This can cultivate learners' skills to utilize knowledge, skills, and thinking abilities acquired in various subjects within a single project. It is considered that implementing "Bridging Exploration STEAM Model" before "Integrative STEAM Model" should be important.

As discussed above, it can be pointed out that the three models are not standalone but rather crucial when combined. Learners acquire technological knowledge and skills in "Seeds Application STEAM Model", and learn interdisciplinary approaches in "Bridging Exploration STEAM Model." With these as premise, it is expected that learners engaging in projects by "Integrative STEAM Model" could form their authentic, transdisciplinary problem-solving abilities such as 21st century skills. Especially in junior and senior high schools where subjects are prone to be silo, it is considered important to construct curriculum through the appropriate combination of these three models when implementing STEAM education.

4. Conclusion

In this paper, we have organized the trends in STEAM education in Japan and introduced the outcomes of the development of a Japanese-style STEAM education learning model undertaken by Hyogo University of Teacher Education. Currently, we are conducting practical research based on the developed learning model in affiliated elementary and junior high schools, in public schools of surrounding areas. In the future, while considering the constraints of the national curriculum in Japan, we aim to further develop easily disseminated learning models and accumulate diverse practical examples. Especially, we should try an examination of STEAM units that utilize combination of physical and digital technologies, consider their implementation in junior and senior high schools.

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Abstract

This study aims to develop hands-on educational materials to support beginner students in learning about electric and electronic circuit designs. In Japanese school education, students are supposed to learn about electricity in elementary school, however, the curriculum focuses on scientific understanding, with few opportunities to learn about design and fabrication. However, learning about circuit design is useful for developing STEM literacy because students deal with a cross-cutting approach to science, technology, engineering, and mathematics. Our research has shown that an understanding of these connections acts as a foundation for circuit design. Furthermore, we attempted to construct a model of the thinking process of circuit design and demonstrated that the transition between the four types of concepts occurs the back-and-forth between synthesis and analysis thinking. Therefore, to support the learning of circuit design for beginners, hands-on teaching materials that ease the difficulty of understanding concepts related to circuits and activate thinking through immediate feedback of results would be effective. We developed circuit materials that could be recombined using parts for electronic components molded by a 3D printer and magnetically attached wires. On being asked to work on a circuit design problem using hands-on materials, students demonstrated interest in the problem and a trial-and-error approach to solving it.

Key Words: Circuit design, Hands-on, Easy prototyping, Conceptual understanding

1. Introduction

This study aims to develop hands-on educational materials to support beginner students in learning about electric and electronic circuit designs. The background of this study is the following social situation in the world or Japan. Recent breakthroughs in Artificial Intelligence (AI) and Internet of Things (IoT) have been dramatic, leading to growing significance in technology education. Hardware technologies related to electricity and electronics have contributed to establishing a foundation for these innovative technologies. Therefore, children's learning about electricity and electronic circuits leads them to learn the principles of technologies that support their lives and society. To understand the technology of electricity and electronic circuits, children should be able to think scientifically and logically about electrical phenomena and the mechanisms of electrical devices. Moreover, learning to create circuits is important for developing human resources who will be leaders in innovation and as STEM professionals. Circuit design is the core focus of this study. The circuit design process, owing to its reliance on engineering knowledge, is considered to have a direct connection to the development of STEM literacy and play a role in shaping children's career prospects. This report discusses the Japanese curriculum on electricity, the development of thinking models, and hands-on teaching materials for circuit design and presents the results of implementing these teaching materials. Note that the title "beginner" is intended primarily for K-12 students.

Regarding electric circuits, in Japan, "technology" is the main subject that develops design thinking, while "science" promotes understanding of scientific concepts. "Technology" is set only in junior high schools and focuses on engineering in the context of various technology. In "technology," students learn about basic technology systems and the importance of maintenance and inspection. They also learn about the ingenuity of problem solving that is incorporated in technology. Furthermore, students learn to identify and solve problems in their lives and society by designing and fabricating. They also learn how to evaluate, improve, and modify the process and results of production.

The Japan Society of Technology Education, a leader in technology education research in Japan, published "The New Framework of Technology and Engineering Education for Creating a Next Generation Learning" in 2021. It describes "the engineering design process" as a process to optimize technology with the help of engineering-related science. The process includes situations in which the seeds are explored in an experimental science context, such as experimentation, prototyping, and simulation. Since experiential learning is considered to be effective for science learning activities related to engineering, the development of appropriate curricula and teaching materials for this purpose is required for technology education research.

"Science" is a subject taught from the third grade of elementary school, and its primary goal is to develop the competence to solve problems about natural things and phenomena scientifically. Since "science" is a subject focusing on natural science, the primary content of study is phenomena related to electromagnetism regarding electric circuits (Ministry of Education, Culture, Sports, Science and Technology, 2017a, 2017b). In the third grade, students learn about conductors and insulators using a simple circuit with a dry-cell battery and a light bulb as a load. In the fourth grade, students learn about the differences in electric current by comparing circuits using two dry-cell batteries: one in series and the other in parallel. Moreover, they learn how to represent circuit diagrams and symbols. In this section, students learn that regardless of real components are placed, if they are connected in the same way as in the circuit diagram, they are isomorphic circuits. In the fifth grade, students learn about the relationship between electricity and magnetism, including the principles of electromagnets and motors. In the sixth grade, students learn that electricity can be converted into light, sound, heat, and motive power, as well as electricity generation and storage.

Comparison of the number of hours allocated to “technology” and “science” classes in compulsory education in Japan reveals the following: technology classes are allocated for only 87.5 hours in junior high schools, whereas science classes receive 405 hours in elementary schools and 385 hours in junior high schools, for a combined total of 790 hours. Therefore, science plays a central role in the study of electric circuits. In Technology, the number of hours spent is extremely low, and students have few opportunities to design and fabricate electrical circuits. Therefore, it is necessary to develop instructional methods and materials that enable students to engage effectively in circuit design learning.

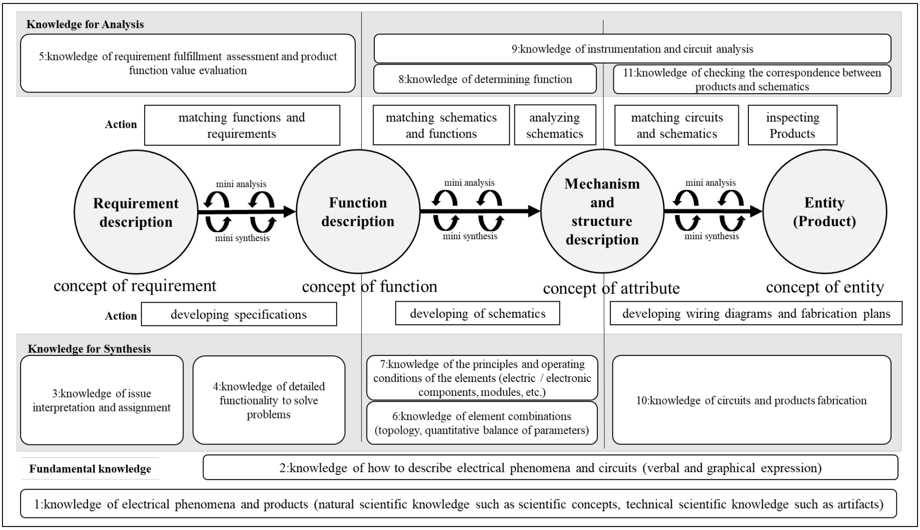
2. Literature Review

Although there have been several studies dealing with circuit design and fabrication, these have been conducted without sufficiently defining the type of behavior involved in circuit design and the type of knowledge used in designing circuits. Therefore, we constructed a model to explain the exact meaning of circuit design. In constructing the model, we focused on design studies, an academic field that examines the subject of design.

The model used to represent design is a generalization of the semantics of design, and focuses on semantic transformation in design. Suh (2001) and Yoshikawa (1979) attempted to explain this semantic transformation process using the axiomatic theory. According to the theory organized by Suh, the design world comprises four domains, which can be expressed as customer, functional, physical, and process domains, and design is developed by “mapping” between domains. Yoshikawa proposed general design theory, which aims to understand a general design processes and principles, and described a series of processes to obtain the optimal solution by manipulating design knowledge in a set-theoretic approach.

In design studies, “design” is considered to be an act of integration, in which an entity is composed of functions and attributes, as described above, and this process is called synthesis. In design studies, “design” is often regarded as an act of integration, wherein an entity is formed by combining functions and attributes, as described earlier. This process is commonly referred to as synthesis. Furthermore, the analytical process of evaluating functions and attributes from the entity is called analysis. Design can be viewed as an intellectual and engineering activity conducted by iterating back and forth between analysis and synthesis (mini-analysis and mini-synthesis) as required. Based on this concept, we developed a model to explain circuit design in cooperation with engineers in semiconductors, integrated circuits, and electronic circuit design regarding knowledge and behavior in circuit design (Figure 1, Ishibashi et al., 2023a).

Figure 1.
Knowledge and behavior structure models for circuit design.



The model presented in Figure 1 illustrates that to conduct circuit design, engineers must synthesize and analyse concurrently while effectively using knowledge to match the requirements. In particular, the process of mapping from the concept of function to that of attribute is a situation in which scientific and technical knowledge of electricity appears to be required. However, understanding the scientific concepts related to electricity is difficult for children, and various misconceptions exist. Various studies on misconceptions regarding electric circuits have been conducted in the field of science education, beginning with Osborne & Freyberg (1985), and so on. Engelhardt & Beichner (2004) developed a test to comprehensively assess conceptual understanding. Based on this test, we investigated the relationship between conceptual understanding and the ability to design using a conceptual test in which circuit concepts were further subdivided into six categories: connection, shortcut, resistance, current, voltage, and power (Ishibashi, 2020). Consequently, we found that a conceptual understanding of connections is a fundamental ability in circuit design. Furthermore, in a later survey we analyzed the results in detail and found that the degree of understanding depended on the position and orientation of the components, despite the connections being the same (Ishibashi et al., 2023b). Therefore, we decided that materials for beginners in circuit design with a high level of flexibility to learn how to connect components and work would be effective.

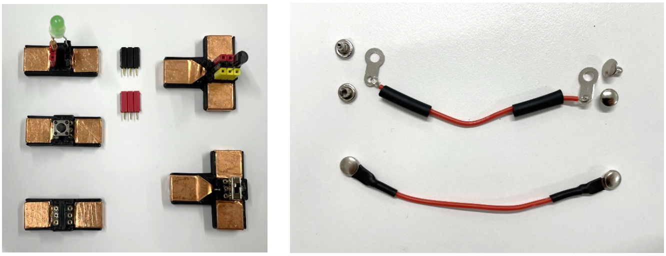
3. Development of Hands-on Materials

Various electrical and electronic circuit materials are used in school education, including clip cords for wiring, breadboards, fixed blocks, and conductive ink. Each has advantages and disadvantages, and a trade-off must be considered in their use. Initially, the following requirements were defined by organizing the properties of materials suitable for beginners: graphical similarity to the circuit diagram, ease of construction and modification, high flexibility in component placement, high flexibility in wiring routes, high visibility of the connection status, circuit expandability (ease of adding components), electrical characteristics (low resistance of wires and contacts), safety (short-circuit protective function), and low cost. Since there is no commercially available product that satisfies all the above requirements, we decided to develop a new product. Moreover, we have developed hands-on materials using conductive tape; however, there have been some issues with the ease of construction, modification, and expandability. In this study, we focused on the following two functions of hands-on materials: First, the materials can be easily reconfigured into any arrangement. Second, it is a safely designed material with automatic circuit protection and warning functions in the case of a short-circuit caused by a student's faulty wiring.

3.1. Circuit materials enabling components to be recombined in any layout

A board (component base) for the independent use of electronic components is required to enable a flexible layout and recombination of circuit components. In addition, we must devise a method that makes it easy to rearrange the wiring. Therefore, as an idea for the materials, we considered of using magnets to attach parts and wires to the board so that the objects could be controlled intuitively. Thus, a real product can be assembled according to the layout of the circuit diagram, thereby facilitating the fabrication of extended circuits. The component base presented in Figure 2 is constructed as follows: First, a 3D printer was used to fabricate the foundation using ABS resin as the base material. Next, a 1 cm square neodymium magnet was bonded to the terminal part, and copper tape was attached to it. Subsequently, a round-pin IC socket (3P) was inserted into the center of the base so that commercially available insertion-mounted components (lead components) could be used, and the leads of the socket were soldered to the copper tape terminals. Finally, two types of component bases were created:1) a component base that can use 2-terminal components such as LEDs, resistors, and tact switches, and 2) a component base that can use 3-terminal components such as selector switches and transistors. For the wiring cords, wires (24 AWG) were soldered to the lug plates, and small nickel caulk (6 mm diameter head) were attached to the terminals so that they could be magnetically connected to the terminals of the component base. Flat caulking was selected so that the circuit could be viewed on a flat plane. The contact resistance between the terminal and the wire was measured using the 4-wire resistance measurement method and ranged from 0.2 to 0.5 Ω.

Figure 2.
Component bases and wire.



3.2. Power supply module with short-circuit protection

To protect the circuit from a short-circuit overcurrent, a power supply module was developed by combining a polymeric switch and a piezoelectric buzzer (Figure 3). The power-supply voltage was 3.0 V (two AA batteries). When this module is switched on, the pilot indicator lights up (green LED). When a short circuit occurs, the polymeric switch is activated and becomes highly resistive, thereby protecting the circuit. At this time, the entire supply voltage is supplied to the piezoelectric buzzer, and the buzzer sounds, alerting the user that a short circuit has occurred. An overview of these materials is presented in Figure 4.

Figure 3.
Schematic and picture of power supply module.

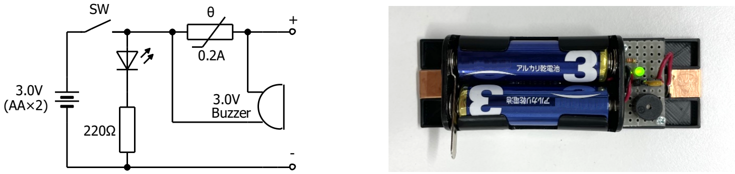
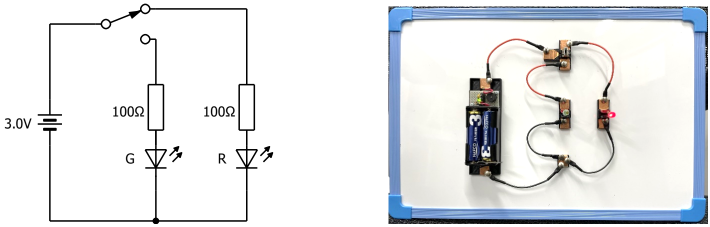


Figure 4.
Overview of hands-on materials and circuit example.



4. Practice and Result

As a case study, we conducted a design experiment using the developed teaching materials with 12 junior high school students in April 2023. First, we explained how to use the materials for approximately 10 minutes, and then had the students work on a design task for 20 minutes. The participants had studied current and connections in elementary school, however, had not learned about voltage, power, or load parallel circuits, which are expected to be learned in Grade 8. Eight design tasks were prepared based on the participants' learning experiences, and the difficulty level gradually increased as the task progressed. The participants were asked to self-evaluate the difficulty of each task on a scale of 1-10 (1: easy; 10: difficult) after completing each task. After the experiment, the participants were asked to evaluate the ease of use of the developed materials on a scale of 1-10 (1: difficult to use; 10: easy to use) in a post-experiment questionnaire. Further, they were asked to evaluate their enjoyment of designing circuits using materials on a scale of 1 to 10 (1: not enjoyable; 10: enjoyable).

Table 1 presents the results. The average response for the ease of use of the materials was 7.9 pts. The average score for enjoyment of the activities was 9.8 pts. The overall correct response rate for the design task is 54.2%. We captured the experiment on video and later checked the work. Each pair of participants proceeded to modify the position and orientation of the components and wiring from their initial status, as presented in Figure 5. Furthermore, when the number of operations was measured, the average number of times the position and orientation of the components were modified per pair was 48.3 times, and the average number of times the wiring was modified was 114.0 times. The average number of times a short circuit occurred was 6.0 times per pair.

Figure 5.
Example of circuit transition (Pair C, Task No.4)

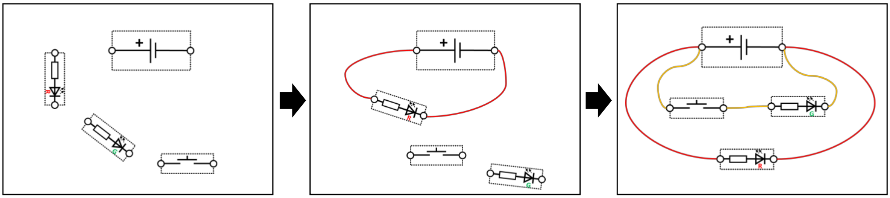


Table 1.
Practice task and result.

Task No.	Task statement (time limit: 20 minutes)	A	B	C	D	E	F	Accuracy	Self-assessment of difficulty
1	When you activate one switch, it lights up in yellow.	✓	✓	✓	✓	✓	✓	1.00	3.7
2	When you activate the two switches simultaneously, it lights up red.	✓	✓	✓	✓	✓	✓	1.00	2.3
3	When you activate one switch, green and yellow light up at the same time.	✓	✓	✓	✓	×	×	0.67	6.4
4	Red is always lighted, and when you activate one additional switch, green lights up even more.	✓	✓	✓	✓	×	-	0.67	5.0
5	When you operate one switch, you can alternate between red and green lights.	✓	×	✓	×	-	-	0.33	8.4
6	When you operate one switch, you can alternate between simultaneous red and yellow lights and a single green light.	✓	✓	-	-	-	-	0.33	7.0
7	Of the two switches A and B, when you activate A, only red lights up; when you activate both A and B simultaneously, red and green lights up; and when you turn off A, all lights go off.	✓	✓	-	-	-	-	0.33	7.3
8	There are two switches, and you can operate the switch from either side to turn yellow on or off.	×	×	-	-	-	-	0.00	10.0

✓:Correct, ×:Incorrect, -:Not tried

5. Discussion

In the above experiment, it was observed that no participants were confused about how to use the materials, and they appeared to concentrate on the task. The average response rate of 7.9 pts for the ease of use of hands-on materials was high, indicating that the materials were suitable for designing and prototyping circuits without disrupting the participant’s thinking. Despite the fact that the percentage of correct answers was 54.2%, which was not high, and despite the fact that there were some incorrect answers and unfinished tasks, the enjoyment of the activity was rated very high, with an average of 9.8 pts. Interpreting the figures in the experimental situation, it was believed that the participants were able to engage in design thinking and construct the circuits while enjoying a sense of satisfaction when they completed and operated the circuits. In addition, the method of pair work, in which participants proceeded while sharing opinions with others, may have influenced their evaluation of enjoyment.

Regarding the frequency of operations and transitions presented in Figure 5, the participants frequently changed the positions and orientations of the components and were able to adjust the layout as required to facilitate problem solving. Breadboards are often used for prototyping electronic circuits; however, beginners are often confused by the restrictions on the position and orientation of the components on breadboards. Using these materials, the position and orientation of the components can be changed flexibly, allowing for the immediate testing various intuitive ideas. However, some of the subjects attempted to find some electrical meaning in the positions and orientations of the components on the circuit, although they were actually meaningless, such as “If I flip the direction of the layout of plus and minus, something will change and I will be able to complete the circuit.” Therefore, if beginners are required to engage in circuit design using these materials, it is expected that their actual circuit concepts will be clarified. In addition, the frequency of wiring changes was extremely high, indicating that the subjects engaged in a trial-and-error circuit design. The features of the materials are that they are not a simulation. However, they are a verification using an actual operation, obtaining feedback from it, making modifications, verifying again, and obtaining feedback again, all in the short term. As evidence for this, we observed that some participants attempted to understand the behavior of the circuit by analyzing what was wrong and how wrong it was when they made a mistake in the experiment. They also observed the search for the error point and modified it, triggered by a short circuit and buzzer sound. Therefore, in addition to helping beginners design and prototype circuits, the materials can also be used to investigate the actual state of beginners’ analysis and synthesis, as they enable the analysis of their thinking process and trial-and-error approach.

In the above, it is possible to adopt this material into learning activities for teaching technology studies in Japan. As mentioned in the introduction, Japanese technology education includes engineering. By using this material, students can connect to the learning of experimental scientific seeds exploration through experiments and prototyping. In this way, it is expected to develop the fundamental competencies of the engineering design process.

6. Conclusion

In this study, we developed hands-on materials for circuit design aimed at beginners, which comprised enabling components to be recombined in any layout and a power supply module with short-circuit protection. We conducted design experiments with junior high school students. The developed materials encourage beginners' analysis and synthesis, are suitable for beginners, and can be used with interest. In addition, these materials can include capacitors, transistors, and various sensors, and can be used as a peripheral of several computers. Therefore, they can be used in class to stimulate ideas. Future tasks include investigating the educational effects on beginners analyzing the thinking processes of designers using these materials in detail.

7. Acknowledgement

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Analyzing the National Technology Education Curriculum for Elementary and Middle Schools in Korea

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Abstract

The purpose of this study is to compare and analyse the content elements that have changed between the 2015 and 2022 curricula at the elementary and middle school technology education levels. To achieve the objectives of this study, a comparative analysis of the existing 2015 curriculum and the revised 2022 technology curriculum literature was used. The content of technology education in elementary and middle schools was compared and analysed in terms of maintaining, transforming, moving, reducing/deleting, and adding. The results of the analysis were revised and supplemented in consultation with technology education experts through a committee. The results of the analysis of the elementary and middle school technology curriculum are as follows. First, the curriculum has shifted from existing technology systems and technology utilization to technological problem solving, innovation, sustainable technology, and convergence. Second, one of the topics that was significantly reduced or eliminated from the elementary school content was information and communication. Third, at the level of affiliation, the newly added contents were construction technology and AI to connect the contents of elementary and secondary technology education. Fourth, in the transportation technology topic in middle school, the focus is on transportation and logistics. Sixth, the robotics topic in middle school has been reorganized into electrical and electronic components and circuits, mechanical components and motion, and robotics and control. Seventh, a topic on construction technology was introduced in elementary school to strengthen the connection between elementary and middle school. Eighth, the ICT topic of AI technology are newly added. Finally, the biotechnology topic has changed to focus on advances in biomedical engineering and the development of new drugs to prolong life.

Keywords: Korean Technology Education Curriculum, Analyse technology curriculum, Compare technology curriculum

1. Introduction

The Korean curriculum revision system has changed from a full-scale revision to a partial, ongoing revision system. In other words, it can be said that the curriculum revision system has improved from a 'one-time revision and full-scale revision system' to a 'frequent revision and full-scale revision system'. The ongoing revision method means that the curriculum is revised as and when necessary (Ministry of Education, 2015). Accordingly, the new technology curriculum was revised and published in December 2022. In fact, the design of the technology curriculum is oriented toward "learning connected to life" and "reflection on the learning process," which are the directions of the curriculum revision. As a common curriculum for elementary and middle schools, the content areas of technology consist of 'technological problem solving and innovation', 'sustainable technology and convergence', and 'digital society and artificial intelligence' (Kwon, et al., 2022).

Therefore, the purpose of this study is to explore the changes in the content and achievement standards of the revised elementary and middle school technology curricula based on the principles of curriculum design. The main question of this study is: "What are the main changes and focuses of the revised technology curriculum?". To accomplish the objectives of this study, the literature of the revised 2022 technology curriculum was analysed. The content of technology education was analysed in terms of maintaining, transforming, shifting, reducing/deleting, and creating new content by comparing the 2015 revised curriculum with the 2022 revised curriculum, and the results of the analysis were revised and supplemented by consulting with experts through academic seminars. Among the terms presented in this paper, Practical Arts is simply defined as "a subject taught in the 5th and 6th grades of elementary school, and the educational content consists of technology, home economics, and agriculture."

2. 2022 Revised Technology Education Curriculum

2.1. Overview of technology education in Korea

Technology education in South Korea is mandatory for students from elementary to high school. In elementary school, technology education is taught in the Practical Arts curriculum, and students in grades 5 and 6 spend 1-2 hours per week learning. The main content is transportation technology, information and communication technology, and invention activities. In middle school, technology is taught separately in the "Technology and Home economics" subject. Technology education is mainly taught in grades 1-2 for one hour a week. The main contents are manufacturing technology, construction technology, transportation technology, communication technology, biotechnology, and invention. In high school, technology is also taught as an optional course in the "Technology and Home economics " curriculum. Technology is mainly taught in the first grade and is taught for one hour per week. The main contents include advanced manufacturing technology, construction technology, transportation technology, communication technology, biotechnology, creative engineering design, invention, and entrepreneurship.

2.2. Overview of curriculum design

The design of the technology curriculum is oriented toward the curriculum revision directions of "learning connected to life" and "reflection on the learning process. In addition, the topics of 'ecological transition education', 'democratic civic education', and 'digital and AI literacy education' are addressed in the goals, content system, and achievement standards of the technology department. As a common curriculum for elementary and middle schools, the content areas of the technology department consist of "technological problem solving and innovation," "sustainable technology and convergence," and "digital society and artificial intelligence" (Ministry of Education, 2022).

In the content areas of the technology curriculum, 'Technological problem solving and innovation' and 'Integration with sustainable technology', the ability to understand technological knowledge, the ability to solve technological problems, and the ability to practice technology were set as the three curricular competencies of the technology curriculum to reflect the essential characteristics of the curriculum (International Technology and Engineering Education Association, 2020). The 'technological problem solving and innovation' and 'integration with sustainable technology' areas were organized into two areas considering the curricular themes of technology literacy and problem solving and the general direction of 'creative innovation' and 'sustainability'. In the area of 'technological problem solving and innovation', the core concepts are technology literacy, problem solving through design, the value of invention, and manufacturing and transportation technology. In this area, students were encouraged to develop an understanding of the nature of technology, technology literacy, and the ability to creatively solve problems such as manufacturing and transportation technology. The core concepts of the "sustainable technology and convergence" area include structures and construction, robotics and control, information and communication, AI (artificial intelligence), sustainable biotechnology, and technology and ethics. This area is designed to develop students' ability to solve problems in construction, information and communication, and biotechnology in a convergent manner. In particular, the curriculum was designed to strengthen the connection between elementary and middle school technology areas and to ensure that the learning content is appropriate while aiming for the latest future technology trends (Ministry of Education, 2022).

2.3. Characteristics and goals of technology education curriculum

The areas of 'Technological problem solving and innovation' and 'Convergence with sustainable technology' in the technology course aim to equip students with technology literacy by forming knowledge and understanding of technology related to human innovative activities, thinking processes and skills, and pursued values and attitudes, and in the process, to express and develop thinking on technological problem solving. It also provides experiences in the learning process and technological problem-solving process to design, produce, maintain, and evaluate knowledge about technology and society, materials and manufacturing, structures and construction, energy and transportation, automation and information and communication, life and medical fields, and food resources that correspond to the content elements of technological studies. Learning experiences in the field of technology provide values that are internalized in the learning process and results, and values that are externally oriented and achieved (Lee, 2022). In addition, "technology" has the characteristics of "technological knowledge" in terms of academic structure, "technology literacy" in terms of educational goals, "technological problem solving" in terms of educational methods, and "technology career exploration" in terms of career education. In addition, the area of 'Digital society and AI' in the Practical Arts subject is linked to the information curriculum in grades 1-3 of middle school and aims to foster the ability to recognize the changing world and solve real-life problems using AI based on computational thinking (Lim, & Kwon, 2019).

According to this context, in technology subjects, students develop subject knowledge, performance capabilities, values, and attitudes to explore problems in everyday life, recognize the impact of problem solving on individuals and society, and improve family life, technology, and information literacy. Based on this, it is designed to lead a proactive life, and the specific goals are as follows. First, students recognize the correct value of technology through an understanding of the concepts and characteristics of technology, technological problem solving, and inventions, and develop technological knowledge through creative and innovative technological practices based on a cooperative attitude. Second, students develop technological problem-solving skills related to the fields of materials and manufacturing, structures and construction, energy and transportation, robots and control, AI and information and communication, life and medicine, and food resources. Additionally, based on convergent thinking and experience, students gain a proper understanding of the world and activities of technology and explore career paths.

2.4. Key ideas of Technology subjects

There are four main core ideas in the area of ‘technological problem solving and innovation’. Technology is an innovative problem-solving activity to meet human needs and desires, and should be utilized to drive human civilization and have a desirable impact on society, culture, and economy (Lee, 2022). Humans creatively solve inventive problems through the process of technological problem solving, and the protection of intellectual property and invention and innovation increase the value of technology. The development of creative products is a technological problem-solving process and requires design activities and the utilization of various materials and tools to produce the product (Lee, 2006). Finally, transportation using green energy is an alternative to overcome resource depletion and environmental problems, and the establishment of innovative transportation and logistics systems enables efficient transportation of products.

There are four key ideas in the area of 'convergence with sustainable technologies'. Construction technology applies various design, construction, and maintenance methods for comfortable, convenient, and safe living, and is valuable as a foundation for the performance of other industries. Robots are composed of hardware such as mechanical elements, electricity and electronics, and software that controls them, and are utilized in various fields of society as a product of advanced convergence technology in which various technologies and knowledge are applied (Ministry of Education, 2015). The development of ICT has contributed to the exchange and globalization of information and culture through overcoming time and space, and it leads humans to new areas by fusing with various technologies. Biotechnology is being developed by converging with various technologies, and the utilization of food resources and the experience of agricultural circulation are the basis for sustainable future life.

3. Comparative Analysis of Technology Education Curriculum

The content of technology education in elementary and middle schools was analysed in terms of retention, transformation, movement, reduction/deletion, and new content by comparing the 2015 and 2022 curricula. The content in the technology area was analysed in terms of whether the content remained the same as in the previous curriculum, was similarly modified, was moved to a non-technology Home Economics course, was reduced or deleted, or was newly created.

3.1. Content analysis of elementary school technology curriculum

A comparison of the content elements of the revised 2022 curriculum and the 2015 curriculum for elementary schools is shown in Table 1, which includes the following themes: invention, transportation technology, robotics, information and communication technology, construction technology, world of work, and AI.

Table 1.
Comparison of contents between the 2015 curriculum and the 2022 curriculum for elementary school technology education

Content	2015 Curriculum	2022 Curriculum	Remark
Invention	·Invention and problem solving ·Protection of personal information and intellectual property	·Meaning of invention and invention ·Technical problem solving and invention thinking techniques ·Concept of inventions and patents ·Importance of intellectual property rights	new content
Transportation technology	·Transportation technology and life ·Safe maintenance of means of transportation	·The meaning of transportation and the development of transportation means ·Components of means of transportation	transform
Robot	·Function and structure of robots	·Robot concept and operating principle ·Understanding robot convergence technology	new content
ICT	·Understanding software ·Procedural problem solving ·Programming elements and structures	·Characteristics of digital technology and types of digital content	reduction
Construction technology		·Concepts of construction technology and eco-friendly structures	new content
Occupational World	·The world of work and occupation ·Self-understanding and career exploration	.	movement
AI	.	·Concept of computer ·Problem finding and problem-solving procedures ·How to give commands to a computer ·Types and expression of data ·AI in daily life	new content

As shown in Table 1, the contents of the elementary school technology area were reduced to information and communication. This is because existing information and communications dealt with computer software and hardware, but as the curriculum was revised and a new area of artificial intelligence was added, the content was adjusted. The newly added contents included invention patents, robot convergence technology, construction technology, computers, and artificial intelligence. These changes in educational content are analysed and summarized in a simple table as shown in Table 2.

Table 2.
Content changes in elementary school technology areas in the 2022 curriculum

Category	retention	transformation	movement	reduction/ deletion	new content
Invention	1	2	.	.	1
Transportation technology	1	1	.	.	.
Robot	1	.	.	.	1
ICT	.	.	.	3	1
Construction technology	.	.	.	.	1
Occupational World	.	.	2	.	.
AI	.	.	.	.	5

※ unit: number of content topics

Table 3 shows the increase and decrease in the number of achievement standards in the elementary technology curriculum. The number of achievement standards in a curriculum plays a very important role in textbook development. Because textbooks are written in terms of achievement standards, the number of achievement standards is used to describe the weighting of units.

Table 3.
Changes in achievement standards for elementary school technology areas in the 2022 curriculum

Category	2015 Curriculum	2022 Curriculum	Increase/ Decrease	Remark
Invention	3	3	0	.
Transportation technology	3	2	-1	content Integration
Robot	2	3	+1	new content
ICT	5	2	-3	deletion
Construction technology	.	1	+1	new content
Occupational World	2	.	-2	movement
AI	.	5	+5	new content
Total	15	16	+1	

As shown in Table 3, in terms of the achievement standards in the technology course, the decrease was in transportation technology and information and communication technology. The topics of the world of work, understanding the meaning and importance of work and occupation, and understanding oneself to find a job that suits one's aptitude, interest, and personality, were moved to the Home Economics course, and the topic of artificial intelligence was significantly added.

3.2. Content analysis of middle school technology curriculum

A comparison of the content elements of the middle school technology curriculum with the 2022 revised curriculum and the 2015 curriculum is shown in Table 3. The topics of the content elements are divided into technology overview, invention, manufacturing technology, construction technology, transportation technology, information and communication technology, and biotechnology, and the comparison results are shown in Table 4. As shown in Table 4, the newly added contents were visualization of invention ideas, materials and robots, logistics systems, electrical and electronic circuits, artificial intelligence technology, and biomedical engineering.

Table 4.
Comparison of content between the 2015 curriculum and the 2022 curriculum in the middle school technology area

Category	2015 Curriculum	2022 Curriculum	Remark
Technology overview	·Development of technology ·Technology and social change ·Appropriate technology ·Sustainable development ·Use of technology and standards	·Understanding technology and future society ·Use of technology ·Appropriate technology ·Technology standardization ·Convergence of technology and the future	retention
Invention	·Technological problem solving ·Realization of invention ideas	·Technological problem solving ·Idea visualization and drawing ·Inventions and intellectual property	new content
Manufacturing technology	·Manufacturing technology system ·Solving problems in manufacturing technology	·Types and use of materials ·Product design and production ·Machine elements and movement ·Robots and Control	reduction/, new content
Construction technology	·Construction technology system ·Construction technology problem-solving	·Building structures and social infrastructure ·Planning, design, construction and maintenance of structures ·Sustainable construction structure model	transformation
Transportation technology	·Transport technology system ·Problem-solving in transportation technology ·New and renewable energy	·Eco-friendly energy resources ·Transportation means and logistics system	new content
ICT	·Communication technology system ·Communication technology problem-solving ·Media and mobile communications	·Electrical and electronic components and circuits ·Information and communication and AI technology	reduction/ new content
Biotechnology	·Future technologies and biotechnology	·Biotechnology and sustainability ·Biomedical engineering	new content

Table 5 shows how the content of the middle school technology area has changed in the 2022 revised curriculum. In other words, no content elements were moved to other areas, and most of them were newly created with reduced content. For example, logistics systems in transportation technology, artificial intelligence in information and communication technology, and biomedical engineering in biotechnology are representative.

Table 5.
Content changes in the middle school technology area in the 2022 curriculum

Category	retention	transformation	movement	reduction/ deletion	new content	Remark (new content)
Technology overview	1	1	.	.	1	convergence technology
Invention	1	.	.	.	2	visualization, intellectual property
Manufacturing technology	1	1	.	1	2	materials, robots
Construction technology	1	.	.	1	1	architectural structure
Transportation technology	1	.	.	1	1	logistics system
ICT	.	.	.	1	2	electrical and electronics, AI
Biotechnology	1	.	.	1	1	biomedical engineering

※ unit: number of content topics

The number of achievement standards is very important when writing textbooks according to the curriculum or in classes. Table 6 shows how the achievement standards for middle school technology areas have changed in the 2022 revised curriculum.

Table 6.
Changes in achievement standards for middle school technology areas in the 2022 curriculum

Category	2015 Curriculum	2022 Curriculum	Increase/ Decrease	Remark
Technology overview	5	4	-1	Content integration
Invention	4	4	0	
Manufacturing technology	4	3	-1	Content deletion and integration
Construction technology	3	3	0	
Transportation technology	5	4	-1	reduce content
ICT	4	3	-1	reduce content
Biotechnology	2	2	0	
Total	27	23	-4	

※ unit: number of achievement standards

The number of achievement standards in the middle school technology area was reduced in accordance with the policy of the curriculum summary. In the 2015 curriculum, there were 27 achievement standards, but in the revised 2022 curriculum, the number was 23, resulting in 4 achievement standards. By deleting and integrating some of the content elements of the technology and creating new content, this had a significant impact on the number of achievement standards.

4. Discussion and Implications

Based on the analysis of the content of technology areas in elementary and middle schools, which are compulsory education in South Korea, comparing the 2015 curriculum to the 2022 curriculum, the following discussion and timeline is presented (Ministry of Education, 2022).

First, the curriculum content changes in the elementary school technology area are as follows. 1) In the Invention and Intellectual Property unit, the curriculum has been transformed from existing inventions and problem solving to the concepts of invention thinking skills and patents. In other words, the previous curriculum focused on understanding the meaning and importance of inventions through examples of inventions and problem solving applied in daily life, and designing and making creative products using various materials. 2) In the area of transportation technology, we have selected and focused on transportation from existing transportation technologies and means of transportation. In other words, the previous curriculum focused on knowing the meaning of transportation and transportation, explaining the basic elements of transportation, and designing and making transportation using various materials. In addition, students were expected to know and practice the components of a bicycle and how to maintain it safely in real life. However, the revised curriculum emphasizes exploring and creating prototypes of various means of transportation in daily life based on the understanding of the meaning of transportation and the development process of transportation (Gallo, et al, 1993). 3) The robotics area has been changed to emphasize robot convergence technology. In the previous curriculum, students were asked to understand the working principle and application fields through the use of robots in daily life, and to build a robot equipped with various sensors. However, in the revised curriculum, students are encouraged to understand the concept and structure of robots, recognize the importance of robots by experiencing the functions of robots in their daily lives, and develop interest in robots by understanding their working principles through the types and applications of robots. 4) The area of construction technology has been newly created in the revised curriculum, which has made a significant change. Construction technology, which has traditionally constituted an area of technical education, was newly created in response to the lack of connection between elementary and middle schools. Here, the focus is on understanding eco-friendly construction structures, exploring construction structures in daily life, and recognizing the value of construction technology while experiencing simple structures. 5) The content of career occupations was adjusted from the existing technology course to the home economics course according to the adjustment of the curriculum area. This is the result of a shift in the organization process as elementary school's practical subjects are divided into home economics, technology, and agriculture. 6) In the field of information and communication, the content has been reduced and changed from conventional software to digital technology. In the existing curriculum, students look for cases where software is applied and think about and apply the sequence of problem solving by procedural thinking. In the new curriculum, the information content has been greatly reduced due to the addition of artificial intelligence content. 7) There was a big change as the artificial intelligence topic was newly created and introduced. In the Korean curriculum, the content of artificial intelligence is included in the ‘Information’ subject in middle schools. However, since there is no information subject in elementary schools, artificial intelligence was introduced as a technology area in the ‘practical arts’ subject, which includes information and communication content.

Second, the curriculum changes in the technology area of middle school are discussed as follows. 1) Convergence was emphasized in the content on the overview of technology, and students were asked to solve convergence technology problems and evaluate the process and results for sustainable development and innovation. Understanding that most of the technologies actually used in our lives are based on the convergence of various knowledge, and that the convergence of technologies is accelerating as the development of technology accelerates, it was emphasized to carry out convergence projects based on convergent thinking, user-centered empathy, and positive problem-solving attitudes. 2) Great emphasis was placed on idea visualization in invention and drawing in manufacturing technology. Students were encouraged to develop collaboration, empathy, and communication skills while visualizing solutions to technical problems, creating drawings, and selecting the right tools to build and evaluate prototypes or models. 3) Manufacturing Technology emphasized materials and design instead of manufacturing technology systems. Understanding the types and properties of materials, selecting the right materials for the right purpose, practicing safe processing methods, recognizing the value and necessity of design, and selecting the right tools to make products safely. 4) In Construction Technology, instead of the system of construction technology, students explore innovative cases of construction structures and explore the planning, design, construction, and maintenance methods for different types of construction structures to design, build, and evaluate models of sustainable construction structures that meet user needs and given environments and conditions. 5) In transportation technology, instead of the transportation technology system, various transportation means and logistics systems are understood, and development processes, characteristics, and innovative use cases are investigated to forecast the development of the transportation field. In addition, we were asked to understand problems related to transportation and logistics systems and find solutions. 6) In Transportation Technology, instead of transportation technology systems, students were asked to understand various transportation means and logistics systems, investigate their development process and features, and innovative use cases to forecast the development of the transportation field. 7) In Biotechnology, students were asked to investigate cases of biotechnology utilized in the medical field for human health and life extension, and to explore, realize, and evaluate biotechnology and solutions to problems. In other words, students were asked to recognize the importance of biotechnology and bioethics based on the understanding that biotechnology has contributed to the development of medical engineering and new drugs for human health and life extension.

5. Conclusion

The following conclusions are based on the analysis of the technology domain. First, in elementary school, the subject that has seen the most reduction and deletion in the revised curriculum is information and communication technology. Students were expected to experience the basic programming process using programming tools and understand the structure of sequence, selection, and repetition by designing simple programs to solve problems, but this content was replaced by the use of digital technologies and devices.

Second, construction technology and AI were newly added as part of the connection between primary and secondary technology education. Construction technology has been expanded to include an overview at the level of one achievement standard, and artificial intelligence has been greatly emphasized with five achievement standards.

Third, in Invention and Intellectual Property, the traditional concepts of invention and problem solving have been transformed and reformulated into the concepts of inventive thinking and patents. The understanding of the technical problem-solving process is still emphasized, and the activity of conceiving and making creative products using various materials is emphasized. The relationship between invention and patent is newly understood, and the importance of intellectual property rights is recognized through patent infringement cases.

Fourth, transportation technology was selected and focused on transportation in elementary school, while logistics systems were emphasized in middle school. The emphasis was on designing and making transportation using various materials, and prototypes of various transportation methods using eco-friendly energy were made to recognize the value of transportation technology.

Fifth, the robotics unit has been changed to emphasize robotics convergence technology. Students were asked to understand the concept and structure of robots, experience the functions of robots in their daily lives to understand the working principle of robots and robot convergence technology, and build a simple robot and apply coding and programs to operate an AI robot.

Sixth, the topic of construction technology was newly introduced in elementary school to strengthen the connection between elementary and middle school, i.e., to understand eco-friendly construction structures, explore construction structures in daily life, and experience simple structures. In middle school, the entire process of design, construction, and maintenance of construction technology structures was emphasized.

Seventh, in information and communication, elementary school students were encouraged to develop the ability to utilize digital devices by creating presentations using digital devices and digital content authoring tools and sharing them in cyberspace, as the content was reduced and changed from traditional software to digital technology. In middle school, students were asked to understand and find solutions to problems related to information and communication and artificial intelligence technologies. Eighth, a new biotechnology topic was created to focus on advances in biomedical engineering and the development of new drugs to extend life.

Finally, a new elementary school AI topic was created to strengthen the connection between elementary and middle school. It focuses on exploring real-life problem-solving examples using computers, representing algorithms in different ways, writing programs, and exploring the types and forms of data that can be used for AI.

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