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Review:

Trends of Technology Education in Compulsory Education in Japan

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If we look at an overview of technology education in the world, we realize that technology education in professional education, as well as in ordinary education, plays an important role in supporting the idea of a technology-intensive Japan. This study focused on the trend of technology education in compulsory education in Japan. Compared to technology education in advanced countries, fewer class hours are spent on technology education in compulsory education in Japan. However, various attempts have been made with robots and programming, mostly under the subject "technology and home economics," at junior high schools. In particular, the future development of programming education implementation can be expected. At the same time, schools face multiple problems, including class hours and a lack of full-time teachers. These problems must be solved to enhance technology education.

Keywords: technology education, compulsory education, robot-using education, programming education

1. Introduction

In the progress of globalization, Japan is currently facing a large change due to low birthrate, longevity, and depopulation. In this situation, the education of the children of the next generation, who will support society after 20 to 30 years, has become more important. In particular, artificial intelligence (AI) and robot technology impact society not only in job employment and industry structure, but also in educational problems. The problem is how we should acknowledge, appropriately use, and control these technologies that are progressing with increasing speed. This is a problem not only for experts of each type of technology, but also for ordinary people. In the USA, the ability to understand, use, and control these technologies is called "technological literacy" [a]. Technology education, not as a type of professional education to nurture engineers, but within ordinary education, aims to develop the technological literacy of every average person.

As science communication for ordinary people has attracted attention in recent science studies, the importance of developing the technological literacy of ordinary people has also been enhanced. This importance was pointed out by Sakurai [1] as well as in the Japan Society of Technology Education [b]. Technological literacy has thus greatly influenced the idea of incorporating technology education into ordinary education in Japan. Categorizing technology education not only as professional education but also as ordinary education is important to maintain the status of a technology-intensive nation.

The author of this paper is specialized in technology education and has been involved in management and examination in robotics competitions in junior high schools and technical colleges. The author has thus seen technology education in both forms as ordinary and professional education. In this paper, we focus on technology education as ordinary education from the viewpoint of the above-mentioned problem. In particular, focus is placed on technology education in compulsory education and its corresponding trends, as most people do not know about the current educational situation. We examine the current situation of technology education in compulsory education and its educational content regarding the latest technologies, including robotics.

2. Current Situation of Technology Education in Compulsory Education in Japan

2.1. Overview of Technology Education in Japan

Many people who took part in the technology component of compulsory education in Japan may recall the junior high school subject "technology and home economics" (hereinafter referred to as Technology Subject). Technology education courses in foreign countries are shown in **Fig. 1**, which was created by the Japan Society of Technology Education [c]. As seen in the figure, the Technology Subject for junior high school students is the only opportunity for technology education as ordinary education in Japan. Primary schools have a subject of Art and Handicraft, but it is actually a part of art education.

On the other hand, technology education as ordinary education in foreign countries begins in an elementary education stage and is widely conducted into the secondary education stage. For example, the UK has a subject called

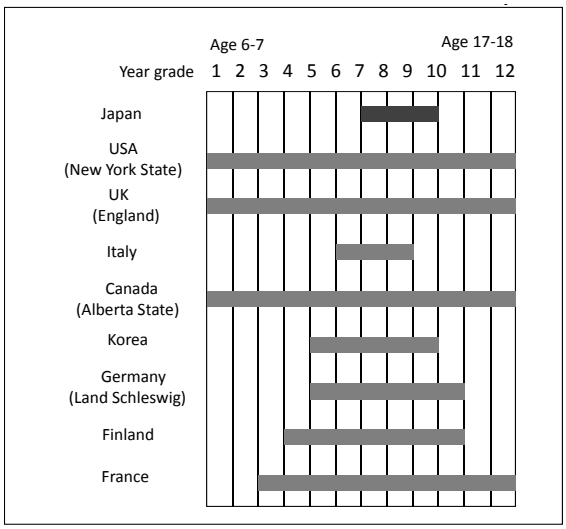

Fig. 1. Examples of technology education in the world, extracted from Ref. [c].

"Design & Technology," which runs from primary schools through high schools, and also a subject called "Computing," to learn information technology [2]. Thus, many countries conduct technology education in a relatively early stage of education, while technology education class hours in Japan are insufficient. In addition to the problem of class hours, there are various problems such as the lack of a full-time teacher for the Technology Subject and the lack of a budget. In particular, the lack of full-time teachers is a critical problem for technology education. The current situation and history (consisting of the change in education content and the change to coeducation of male and female students) of the Technology Subject have been reported by Moriyama and Muramatsu [3] and schools' opinions have been reported by Sato [4] and others.

Even in this situation, there are several advanced activities in Japan. For example, in Suwa city, Nagano Prefecture, a new subject, "Manufacturing" was established more than 10 years ago. It was added to the Technology Subject for students from the first grade of elementary schools to the third grade of junior high schools [5]. In particular, it does not aim simply at the manufacturing process but at manufacturing with the user in mind, in other words, manufacturing from a user's viewpoint. In addition, an attempt has been made to introduce the Technology Subject to elementary schools within the framework of an experimental school system of the Ministry of Education, Culture, Sports, Science, and Technology [d]. Private schools also have made a variety of efforts. For example, Ritsumeikan Elementary School established a "Robotics Course" for the first to fourth grade students more than 10 years ago and accumulates experiences of the advanced education [6]. However, such an advanced education is conducted only at a limited number of schools. For the technology education in compulsory education, it is necessary to examine students' achievements on an academic basis and extend the advanced education across the country.

2.2. Overview of Educational Course of the Technology Subject

The organization of the educational courses of elementary and junior high schools is based on the Course of Study designated by the Ministry of Education, Culture, Sports, Science, and Technology. It is revised every 10 years, and the latest one was released in March 2017. In addition, a detailed manual of the Course of Study was also issued, which is used as a guideline to organize the educational courses at schools throughout the country.

The Technology Subject changed its direction from the previous central idea that emphasized usefulness in our life, namely lifestyle technology, to an idea similar to the above-mentioned technological literacy, with an emphasis on development of not only the relationship between technology, society, and the environment, but also the ability and attitude to evaluate and use the technology appropriately. In the 2017 revision, the Technology Subject expanded, and the content was enhanced in a new direction [7] (**Fig. 2**). Qualifications and abilities that should be nurtured by the Technology Subject include "ability to find technology-related problems from daily life and society," "ability to create a design in a concrete shape by making a prototype, evaluating, and improving through practice," and "ability to solve problems." The fact that the ability to create an idea and design it, as well as to be able to evaluate and improve upon it, are emphasized, is important. It means that there is a focus on more essential technology. As for robotics technology, for example, the Technology Subject widely covers not only "programming for measurement and control" but also "programming of contents" and "cybersecurity" for networks which can be connected to the internet of things (IoT), as well as intellectual properties. As for "evaluation of technology," the Course of Study requires more than just manufacturing, but says, "Let students realize the optimization process of technologies by focusing on social demand, safety, environmental burden, and the economy" [8]. Of course, it is difficult to teach this rich content within the current framework of the Technology Subject of 87.5 class hours (8.6% of a total of 1,015 class hours in junior high school), and ingenious efforts of school teachers must be expected.

2.3. Programming Education at Elementary Schools

Compulsory programming education at elementary schools is now attracting attention. In the current situation with the progress of AI and increasing demand for human resources in IT, foreign countries have begun introducing programming education as a part of compulsory education. The theme "Computer Science is for All Students!" [e] from the White House in the USA is symbolic. In Japan, the 2017 Course of Study of the Technology Subject made the programing for measurement and control in junior high school education compulsory earlier than in other foreign countries, but not in elementary school education. However, after the Sixth Industrial

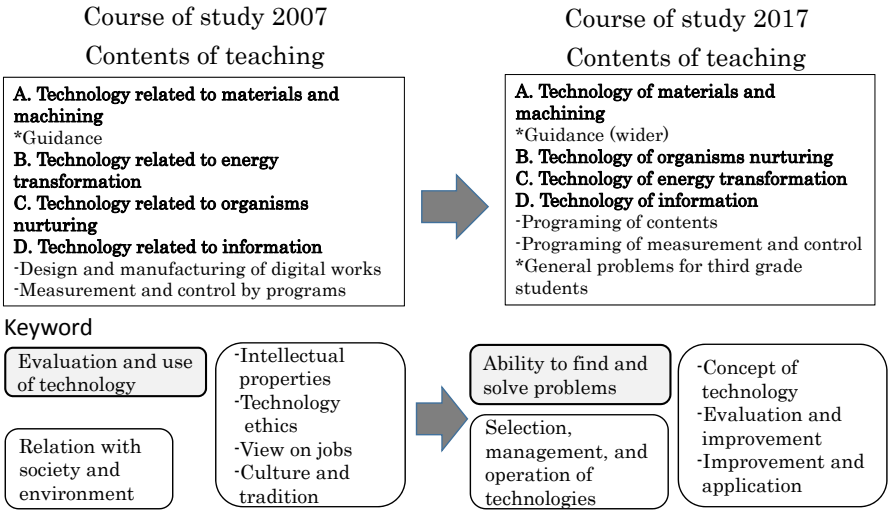

Fig. 2. Comparison courses of study for Technology Subject. Created by the author of Ref. [8].

Competitiveness Council in 2013 advocated for the importance of programming education, discussions centering on programming education began for Declaration on the Creation of the World's Most Advanced IT Nation in 2014. An expert panel [9], which discussed programming education for elementary school students led by the Ministry of Education, Culture, Sports, Science, and Technology, examined detailed directions and the framework. The Course of Study for elementary schools released in 2017 finally dictated compulsory programming education at elementary schools, giving some examples of the programing education conducted in subjects such as mathematics, science, and comprehensive lessons [f].

Programming education in other countries "aims to develop abilities of abstraction, problem analysis, algorithm, data usage, evaluation, and cooperative work under the idea of computational thinking, which includes programming education" [10]. Here, computational thinking has been translated by Nakajima [11] to mean "thinking with computational theory. It is a way of thinking to solve a problem using computer with an emphasis on the correct understanding of the problem so that the computer can solve the problem easily."

On the other hand, in programming education in Japan, "an ability of logical thinking, for example about what kind of combination of actions is necessary to realize a series of intended activities, how symbols that represent the actions should be combined, and how the combination of the symbols should be improved to make the actions closer to the intended activities" is presented as programming-like thinking [9]. There is an argument about programming-like thinking that places more emphasis on operability than on computational thinking. Regardless, it was a large step to make programming education compulsory for elementary school students; technology education-like content has clearly been introduced to elementary schools, although there are practical problems such as the training and nurturing of teachers, environmental development, and budget.

2.4. STEM Education and Inter-Subject Linking

Many advanced countries have put political efforts behind Science, Technology, Engineering and Mathematics (STEM) education in addition to programming education. STEM aims to develop education by integrating these fields. Elementary and secondary curricula using robot educational materials are often conducted as a part of STEM education. As shown with robotics, various academic fields can be linked or integrated to advanced technologies. Therefore, it will become more important to develop links and integrate multiple subjects beyond the existing subject system.

It is actually difficult to develop STEM education in a Japanese education course where the framework of the existing subjects is very strong. However, the 2017 Course of Study introduces a concept called curriculum management that focuses on the mutual relationship between the contents of various subjects and organizes, implements, and evaluates the education course from a cross-subject viewpoint. It also shows some examples of collaboration of the Technology Subject with "science" and "arts and crafts" in elementary schools. From the viewpoint of STEM education, technology education must cooperate with other subjects. This cooperation is ongoing in Japan, including an attempt for inter-subject cooperation in the aforementioned experimental school system. This is another challenge for technology education.

3. Implementation of Technology Education in Compulsory Education in Japan

3.1. Implementation of Robots by Using Education

Let us consider education using robots. The term "robot" includes not only the mechanism but also an automatic control unit in an engineering sense. However, in general, the term is used in a wider sense. For example, an educational material that works with a motor is called a

robot-using educational material. Therefore, we first will give an overview of education using a manually controlled robot.

Education for development of robots in the Technology Subject began around 1991, triggered by Robocon, a robot competition for technical colleges. At first, only a limited number of schools participated in the robot competition convention, but it began attracting attention and became popular. Currently, the largest public competition is a national convention held by the National Junior High School Technology and Home Economics Institute of Education, an academic group of teachers who teach technology and home economics [g]. The first convention was held in 2000, and currently, there are local conventions in each prefecture, a semi-national convention in each district, and a national convention. It consists of various sectors ranging from an introductory sector to an application sector, and many junior high school students participate in the conventions. Besides such public robot competition conventions, many other conventions and competitions are held in various areas. Since these are for junior high school students, the technology level is not as high as that for technical colleges. However, the junior high school students make elaborate robots using limited materials and manufacturing technology under limited regulations. Their attitude for the competition gives a strong impression to visitors. In particular, an in-school robot competition at a public junior high school in Hachinohe City, Aomori Prefecture, attracted attention for its high creativity and technology level [12]. Muramatsu [13], along with many other studies, reported on the current situation and educational effect of robot-using education.

A previous type of robot-using education was mostly conducted as an elective Technology Subject (schools were allowed to introduce elective subjects in addition to the Technology Subject). However, owing to the influence of the reduction in the number of elective subjects designated by the 2007 Course of Study, it became difficult to continue and develop the previous type of robot-using education. The introductory sector requires easier robot-making techniques so that students can make robots in limited class hours. For the application sector, where participants are required to make medium or large robots, most schools use extracurricular activities, not class hours. In addition to this trend, the robots being made in this type of education are changing from manually-controlled ones to those automatically controlled by a computer, partly due to the relationship with programming education mentioned below.

3.2. Implementation of Programming Education

As shown in Section 2.2, the 2007 Course of Study made programming for measurement and control compulsory in the Technology Subject, which had a large impact. The rate of students taking a programming-related subject was less than 20% before this change, but significantly increased after the change. An even larger effect is seen in the price decrease of educational materials for control systems. The educational material market expanded after the Technology Subject was made compulsory, and many manufacturers lowered the prices of robot-controlled cars and LED light control educational materials so that students could buy them. Backed up by the spread of these materials, many schools could conduct programming education for measurement and control in a short period of time. Experiences have been accumulated through the execution of this education. At first, students worked on problems like escaping from a maze. However, programming education is now conducted with more advanced problems, including problems related to life, and the effects of the education are being studied [14].

The impact of making the programming education compulsory has been significant for elementary schools. Since the target of the programming education extended to elementary schools, various groups including NPOs and the education industry, including crammers and social education organizations, began intensive activities. In addition, a number of programming competitions, not only domestic but also international, such as RoboCup Junior [h] and WRO [i], are being held. The Ministry of Education, Culture, Sports, Science, and Technology and the Ministry of Economy, Trade, and Industry have launched multiple projects to support programming education. It is just a bubble of programing education.

A wide range of programming educational materials and robotics educational materials are now expanding. The robotics educational materials are becoming more diversified than in other countries and use easily programmable UI or innovative programming languages. Easy-to-use educational computer boards for a more moderate price, such as Arduino and Raspberry Pi, have been developed. Most programming languages were once procedural language, such as BASIC, but now are block object-oriented language, such as Scratch, which was developed by the Scratch Team of MIT [j]. Related books, such as the one by Abe et al., have been published more often in recent years [15, 16].

In foreign countries, students in the lower grades in elementary schools learn a programming procedure using a robot or puzzle, students of higher grades in elementary schools learn to make a program that contains bifurcation and repetition using a visual language, and students of junior high and high schools learn using a text language [10]. At present, studies and execution of the programming education have begun in various places in this rapid growth of programming education. Schools face many practical problems such as those associated with the training and nurturing of teachers, educational materials, and the educational environment; however, it is expected that high-quality sophisticated execution of programming education will begin after several years, similar to what we have seen with the Technology Subject. At the same time, a major problem of technology education is how to develop continuity and cooperation among the school stages of elementary school, junior high school, and high school using programming education.

4. Summary

In this paper, we provide an overview of the current trend of technology education in compulsory education in Japan from a viewpoint of the importance of technology education not only as professional education but also as ordinary education. We established that the number of class hours for technology education in compulsory education in Japan are lower than in other advanced countries, but that various activities relating to robots and programming are being conducted. In particular, future development of the execution of programming education can be expected, which will significantly depend on the intense class and materials studies being undertaken by school teachers and other involved people. The class studies by Japanese teachers are known as "lesson studies" and are highly rated in foreign countries [17]. However, an excessive dependence on teachers' efforts is a problem not just of the educational society, but also for Japanese-type management. On the basis of the ongoing programming education, we should work to solve many challenges for technology education such as class hours, education courses, public budget and development, support, teacher nurturing, and teacher employment. Support and collaboration from many people who are involved in engineering are necessary to enhance the technology education.

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