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Research Article:

A Historical Perspective of Science Education in Japan: Which Way is it Headed in the Future?

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ABSTRACT

Japan has achieved rapid modernisation compared with other Asian countries, and Japanese students often obtain higher scores on international science assessment tests than students from Western countries that have influenced Japan. The question of what led Japan to attain such a position and what can be expected in the future persists. To understand the future of science education in schools, called *rika* in Japan, as well as its complex and multi-layered status in schools, it is important to employ a historical approach. This study examines the following analytical points: the slogan "Science for all and for excellence," the West's influence, and social changes. This study also explores the pre- and post-World War II eras. Finally, expectations for the near future are discussed. It is known that Japan will continue to develop rika that encompasses both homogeneous and heterogeneous Western science education, considering the global trends in science education. Consequently, while the policy of "Science for all" will be maintained in the near future, "Science for excellence" programmes, such as the "Super Science High Schools" programme, can be extended in terms of the supply of future scientists and engineers. This can be partly at the request of the industrial sector to survive international economic competition based on scientific and technological innovation and to maintain its international status. An important lesson from history is that science, as a part of liberal education, is provided for the individual well-being of scientifically literate citizens, rather than for the nation's benefit. Therefore, the duality of "Science for all and for excellence" should not be considered in terms of binary opposition; "for excellence" should be recognised as encompassed by and a form or part of "for all."

Keywords: History of science education, Japan, *rika*, science

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INTRODUCTION

Japan was the first country in the East to achieve rapid modernisation by learning from the West in the mid-19th century and is now one of the most economically and technologically advanced countries in the world. Additionally, Japanese students have been obtaining higher scores on international tests, such as the Trends in International Mathematics and Science Study (TIMSS) and Performance of International Students Assessment (PISA), than students of other Western countries from which Japan imported science or "scientific technology" (Watanabe, 1990, p. 127) in the mid-19th century.

Why was Japan able to attain such a position, and which way is Japan headed in the future? To understand the current status of science education in Japan and its future, which is complicated and multi-layered in various aspects, it is important to employ a historical approach. Historical research will provide potential answers to this question as science education is constructed socially and historically.

AIMS, RESEARCH QUESTIONS AND RESEARCH METHODOLOGY

Aims and Research Questions

According to Jenkins (2019), "reflection on the past is necessarily limited as a guide of the future" (p. 170). Carr (1962) argued as follows:

> I should rather have called it (note: what is history?) a dialogue between the events of the past and progressively emerging future ends. The historian's interpretation of the past, *his* selection of the significant and relevant, evolves with the progressive emergence of new goals (p. 118: italics by the author).

Reflecting on the history of science education can facilitate an understanding of its socio-cultural contexts, and considering new educational goals can make a certain degree of prediction possible.

This study investigates the historical characteristics of rika (the Japanese term for science education in schools) from the mid-19th century onward when the newly modernised society of Japan was established. To achieve this research aim, the following research question is explored: "Who is science education for?"

In this study, the author investigates the following analytical points: the slogan (or policy) "Science for all and for excellence," the influence of the West, and social changes. Furthermore, this study discusses the pre- and post-World War (WW) II eras and expectations for the near future.

Research Methodology

According to Carr (1962), history "is a continuous process of interaction between the historian and *his* facts, an unending dialogue between the present and the past" (p. 24: italics by the author). Tyack (1976) argued that a historian is "likely to adopt a framework of interpretation that matches one's perception of reality and purpose in writing" (p. 388).

For example, Layton (1984) stated his position when writing the history of the Association for Science Education. This is a historical study, and therefore, it must be inferred that the framework of interpretation of historical facts is based on the historian. The author of this paper has extensive experience in teaching and researching the history of science education, focusing on Japan's *rika,* spanning roughly 30 years at the university. For the historical research included this study, the author analysed many historical government documents, such as regulations, syllabi, and courses of study, and other historical materials, such as periodicals, monographs and textbooks. The author also interviewed witnesses to the history of science education.

Rika **in Japanese and Science in English**

Rika in Japan is generally known as a school subject. However, there was a discussion over its meaning among teachers (Takahashi, 1907) when *rika* was first introduced to the higher elementary school curriculum in 1886. Despite the difference in terminology (e.g., "rika" in Japan and "science education" in schools in the West), they appear to be similar and are identical in terms of subject content; however, there are some differences between the two subjects based on their cultural backgrounds (e.g., Ogawa, 2015; Isozaki, 2014). Why did these differences arise, and where do we observe such differences in Japan's *rika* and Western science education?

Watanabe (1990), a science historian, pointed out that Japanese leaders in the early Meiji era (1868–1912) ignored one of two central elements of Western civilisation (which was Christianity) and were only intensively concerned with modern science. He concluded, "[T]his limited outlook prevented a comprehensive understanding of Western civilization and therefore made impossible a fundamental understanding of modern science as the outcome of human intellectual and spiritual activity" (Watanabe, 1990, p. 22). Similarly, Morishima (1982), an economist, argued, "The Japanese have interpreted this theme of building a Western-standard modern state in a material–physical, and not a spiritual, sense, and so, despite the rapid external and formal westernisation of science, technology, education, economics…, spiritual changes have lagged far behind" (p. 52). Morishima also explained the reason for the use of the Japanese slogan, *wakon yōsai*, which describes the Japanese spirit with Western ability or learning, or Japanese traditions and Western skills. The *oyatoi-gaikokujin* (foreign advisers and teachers) included the British principal of the Imperial College of Engineering in Tokyo (later, the Faculty of Engineering, University of Tokyo), Dyer, who observed that the Japanese could unite many of the best qualities of Eastern ideas and Western thought (Dyer, 1904). Consequently, while external and formal westernisation was rapidly achieved, Western spirituality ideas were rejected. In other words, *wakon yōsai* was similar to "recontextualisation" (Isozaki, 2014).

For example, traditionally, the objectives of *rika* from primary to secondary education levels have encompassed two important terms: *shizen* (nature) and *kagaku* (science). This reflects the differences in the *shizen-kan* (the view of nature) and the components of science between Japan and the West, especially the UK by which Japan was strongly influenced. Morris-Suzuki (2015) stated that images of nature were central to constructing a national identity, especially in Japan, for "molding the imagery of nationhood" (p. 35). Watanabe (1974) argued that in Japan, "nature was a unity, and man lived in it as a part of this unity. In the Western idea, man was not an ordinary part of nature" (p. 280).

From the mid-19th century, *rika* covered four main content areas: physics, chemistry, biology and earth science involving astronomy, geology, meteorology and oceanography. In 1872, when middle school (secondary school for boys) was organised, some components of earth science were placed in the school curriculum by the Ministry of Education. Additionally, in 1877, when the University of Tokyo was established, the College of Science comprised eight departments: mathematics, physics, chemistry, biology, astrology, engineering, geology and metallurgy. Japan's science curriculum has traditionally been a spiral curriculum from elementary to upper secondary schools and has recently been structured with four main concepts: energy, particles, life and the earth. Each corresponds roughly to physics, chemistry, biology and earth science. Therefore, components of earth science have been recognised as an essential part of science in schools. These components demonstrates yet another distinction between *rika* and Western science education.

Although *rika* is a formal school subject like science in the West, in this paper, except to illustrate the special context, the term "science" is used interchangeably with *rika* to avoid confusion.

LITERATURE ON THE HISTORY OF SCIENCE EDUCATION IN JAPAN

Compared with other research topics on science curricula, teaching material development, the cognition of children in science, and science teaching methods, there is little historical research on science education in Japan, which is also the case in European countries (Isozaki, 2021). However, there are distinguished books on the history of science education in Japan, such as those by Hori (1961), and Itakura (1968). Additionally, there is extensive literature on the history of science education in Japan, which is focused on special issues but is limited to a certain period. Except for a few studies on the history of science education in Japan, such as Hashioka (1969) and Hujimoto et al. (1937), almost all the literature is in Japanese. Only a few studies have used comparative history (e.g., Terakawa & Brock, 1978; Isozaki, 2014; 2016; 2021). This study explores science education in Japan from the mid-19th century to the present time and predicts the possible trends in the near future from a historical perspective, with a special reference to the influence of the West.

SCIENCE EDUCATION IN THE PRE-WWII ERA

The Organisation of Science

The newly established Meiji government promptly centralised education, foreign affairs, the military and economics to expedite the formation of a modernised society and nation to avoid colonisation from Western countries. The government employed many *oyatoi-*

gaikokujin and sent many students to the West, especially the UK, the US and Germany (Prussia), to absorb the Western systems involving education.

According to the General Schedule for the Course of Study for Elementary Schools in 1872 and 1873, there were several separate science subjects, such as physics, chemistry and natural history. The Japanese introduced Western science in schools through translated textbooks as "teachable science" (Knight, 1992). For example, the British chemist Roscoe's Science Primers: Chemistry (1872), which aimed to understand scientific principles through a series of chemical experiments and "by bringing it into immediate contact with Nature herself" (Roscoe, 1872, preface), was translated into Japanese to use as school textbooks in 1874. Such translations have traditionally been essential not only for students and scholars but also for the general public to gain knowledge from countries outside Japan. For certain reasons, such as policies emphasising the three Rs (reading, writing and arithmetic) and physical education in lower grades, science was not included in the lower grades. In the absence of a serious debate on the purpose of teaching science only from the perspective of the utilitarian value of science, and due to the paucity of suitable teachers who were proficient in Western science and inadequate laboratories and equipment, science lessons were generally taught by reading textbooks translated into Japanese or oral instruction. The forerunners of science education, such as Goto and Miyake (1885) and Nakagawa (1891), made efforts to devise simple mechanical laboratory equipment for physics and chemistry to teach science during those times.

According to the 1886 Elementary School Order, elementary school was divided into two levels: four-year compulsory–ordinary (later expanding to six years) and four-year higher divisions. At the higher elementary school, the integrated subject, *rika*, was established. According to Kanbe (1938), *rika* was translated from *Naturkunde* in Germany or nature study and elementary science in the US. Finally, in 1891, the objective of *rika* was defined by the Ministry of Education as "to make close observation and experiment with common natural things and phenomena and to develop an understanding of their inter-relations and the relationship with human lives, and to educe (educate) a love of nature *(shizen)* in the minds of children" (Ministry of Education, Science, Sports and Culture (MoE), 1972, p. 100: translated by the author).

In secondary education, the name "girls' high school" appeared in the revised Middle School Order in 1886 as a type of ordinary middle school. The girls' high school was organised by the Girls' High School Regulation in 1895, and *rika* was made compulsory. The girls' high school science emphasised the daily life context. The middle school was organised in 1872. By contrast, there were several separate science subjects, such as physics and botany. Ultimately, in 1931, separate science subjects were integrated into one subject known as rika. Compared with girls' high school science, middle school science was based entirely on academic or pure science.

These different years of the organisation of *rika* were based on the types of schools; particularly in secondary education, the difference was in the characteristics of each school: the girls' high school, which espoused the principle of "a good wife and wise mother" (MoE, 1980), and the middle school, which had a strong link to post-secondary (tertiary) and higher education. Even if the levels of the purposes and teaching content in their studies and the number of lesson hours were different, science was always compulsory for both boys and girls.

The Influence of the West and Social Changes

According to economists like Kondratieff (1935) and Rostow (1956, 1960), the period from the 18th century onwards saw several economic cycles/stages. For example, Rostow (1956;1960) defined the economic stages as follows: (1) the traditional society, (2) the preconditions for take-off, (3) the take-off (Japan: 1878–1900), (4) the drive to maturity (Japan: 1940), and (5) the age of high mass-consumption. The newly modernised society in the mid-19th century was just placed at "the age of railways and mass production" and "the take-off." From the 1890s to the 1930s, a new industrial revolution occurred in the form of heavy industrialisation and wars; for example, the Russo-Japanese War and WWI caused social and educational changes. Historically, education, especially science, technology, engineering and mathematics (STEM) education, was transformed by economic and social change.

Regarding the relationship between economics and education, Rostow (1956) stated, "Education, for some at least, broadens and changes to suit the needs of modern economic activity" (p. 27). Fägerlind and Saha (1983) argued, "Schooling was…regarded in Japan as essential for economic growth...the Japanese example…education can make a direct contribution to economic growth and advancement" (pp. 38–39). Japan's state intervention in education was much stronger than that of the UK, which had achieved the first industrial revolution in the world (Isozaki, 2014). However, as Stephens (1991) argued, this means that education in Japan was provided "for the benefit of the state, not primarily for the fulfilment of the individual" (p. 70).

The 1881 Political Crisis within the government triggered a shift in Japan's national model of politics, economics and education from the UK and US to Germany and since then, the influence of German pedagogy could also be seen in science education. Specifically, Hausknecht taught German pedagogy at the Imperial University of Tokyo. The *herbartianichen Didaktik* was a common teaching method in elementary schools, and science was no exception. Takahashi (1907), Matsuda (1911) and Tanahashi (1913), who were professors and teachers at the Tokyo Higher Normal School, introduced German pedagogy, including science, such as Junge's idea of *Lebensgemainschaft*. Consequently, elementary school science textbooks were edited mainly based on German pedagogy before the Ministry of Education edited national textbooks.

After the Sino-Japanese War (1894–1895), the attendance rate of school-age children for compulsory education gradually rose (from 61.24% in 1895 to 96.56% in 1906) (MoE, 1980). Finally, compulsory education was extended from four to six years in 1907. As a result, every elementary school child had to study science in grades 5 and 6, later starting from grade 4 onward. Under this condition, some efforts to teach science in the lower grades began through experience gained from Germany and the US. For example, the elementary school attached to the Tokyo Higher Normal School created subjects based on the German educational philosophy and pedagogy, *Anschuungsumterricht* for grades 1 and 2 and *Heimatkunde* for grades 3 and 4, which were integrated science and social studies comprising geography and history. The other movement for establishing science at lower grades was based on nature study in the US. The private elementary school named Seijyou shougakkou conducted *shizen-ka* (nature study) at lower grades as an alternative study of science from its establishment in 1917. Yamada and Isozaki (2016) argued that the theory of science at lower grades in that school coincided with American ideas of nature study. Despite these efforts, the establishment of science in lower grades had to wait until the 1940s.

The Russo-Japanese War (1904–1905) and WWI (1914–1918) stimulated the rapid development of Japan's capitalism and the second industrial revolution, which changed to heavy industry. These social changes required human resources in the fields of STEM, and therefore, secondary, tertiary and higher education fields were expanded and reorganised. There were two factors influencing science education during this time: WWI and the introduction of the heuristic method proposed by Armstrong (1903). The expansion of education opportunities also led to the reorganisation of the science curriculum at the middle school level in 1931. Finally, two sciences, "physics and chemistry" and "natural history," were integrated into one subject known as *rika*. This was compulsory and included the following subjects: *ippan-rika* (general science), physics, chemistry, botany, zoology, physiological hygiene, mineralogy and *ōyō-rika* (applied science). *Ippan-rika* was influenced by the US (Isozaki, 2016). However, general science and applied science disappeared in 1941 when science subjects were drastically reorganised due to reforms within school education in wartime.

The Origin of STEM Education and the Emergence of Science for Excellence

During WWII, the Ministry of Education reorganised the education system and created a correlated curriculum at both primary and secondary education levels. Science was integrated into a new subject area, "science and mathematics," both at the elementary and secondary school levels. Science in grades 1 through 3 was first established at this time in Japan; however, the teaching manual, titled "shizen no kansatsu" (observation of nature), was only edited, and students' textbooks were never published owing to a steady campaign to establish science for lower grades based on the idea of learning from direct contact with nature itself from the late nineteenth century onward. In secondary education, science and mathematics included three subjects: *busshō* (physical sciences), *seibutsu* (biology) and mathematics. *Busshō* included components of physics, chemistry, earth science and *rika-kousaku* (technical and engineering work based on science). Although *busshō* and *seibutsu* were implemented in a poor manner and with the limited practice for reasons common in times of war (such as the paucity of teachers and students working at military factories), they can be considered one of origins of STEM education at this time.

The Ministry of Education asked the four Higher Normal Schools of Tokyo, Hiroshima, Kanazawa and Tokyo Girls' (joined later by Kyoto Imperial University) to conduct *tokubetsu* *kagaku-kyōiku kenkyū* (research on special/experimental classes for science education) for elementary and secondary schools' gifted students for the science for excellence programme. The original aim of this research project was "to contribute to the dramatic improvement of science and technology in Japan" (MoE, 1945, p. 27: translated by the author). Even though this project had a short implementation time (January 1945–March 1947), it intended to develop human resources, such as creating future scientists and engineers for the STEM fields. Each Higher Normal School selected gifted students based on their admission policy and provided distinctive advanced science education that enhanced the study of science, mathematics, and technical and engineering work. Professors of Kyoto Imperial University and the four Higher Normal Schools, who were members of each course management committee, sometimes directly instructed students. These facts suggest that this project can be considered one of the origins of the Super Science High Schools (SSH) programme.

Innovative science education, considered the origin of today's STEM and SSH education, was developed and implemented during wartime, even if it could not be fully executed in schools because of WWII.

SCIENCE EDUCATION IN THE POST-WWII ERA

The Reorganisation of Science

After WWII, Japan was occupied by the General Headquarters (GHQ) of the Supreme Commander for the Allied Powers, primarily the US. Education played an important role in democratising Japan in the process of building a new democratic nation. Upon the GHQ's request, the US government sent the US Education Mission to Japan in 1946. Consequently, Japan's education system was reorganised as follows: six years of elementary school, three years of lower secondary school, three years of upper secondary school, and four years of university. Compulsory education was extended from six to nine years during this time. The Ministry of Education provided the course of study for every subject from elementary to upper secondary schools as a national curriculum, including the objectives, teaching contents, and notes. The course of study has been revised approximately every 10 years since then. It is noteworthy that in elementary and secondary schools, all students must study science equally, whereas in upper secondary schools, all students must choose compulsory science subjects based on their aptitude, interests and career paths. Several factors are involved in the revisions of the course of study, such as social changes, the results of analysing data from international and domestic achievement tests, and trends in education worldwide.

For the commencement of the new education system, workshops were held at major universities around the country by the Institute for Educational Leadership (IFEL) of the Civil Information and Education Section of the GHQ. For example, in 1951–1952, the "curriculum and method in natural science" workshop was held at Hiroshima University (IFEL). Participants at Hiroshima University included teachers from the newly organised faculty of education, national universities in western Japan, and consulting teachers of the board of education and secondary school teachers. Through these workshops and the newly established boards of education at prefectural and municipal levels recommended by the US Education Mission, the objectives, teaching methods, theories of science curriculum and teaching units, and science facilities of newly reorganised science based on the course of study were broadcasted among science teachers in Japan. Therefore, the newly reorganised science education system began with the influence of the US under democratic education. Although the course of study issued in 1947 was a draft, it was not mandatory or obligatory; the actual instruction in classrooms was left to each school and teacher. Therefore, the IFEL was an important opportunity for educators.

Similar to the government in the early period of the Meiji era, the newly established Japanese government and industrial society after WWII recognised the important role of science and technology education in rebuilding the nation and industrial and economic growth. Then, the Vocational Education Law was passed in 1951, and the Law for Science Education Promotion was launched in 1953. These facts indicate that, like in the pre-WWII era, the central government continued to take the initiative in making education policies.

The Influence of the Anglo-American Alphabet Curriculum: Rikakyōiku No Gendaika

There were two internal and external factors that revised the course of study in 1969 and 1970. The internal factor was the Japanese government policy for human resource development to sustain and develop economic growth, especially to secure numbers of scientists and engineers as well as their qualities. The external factor was the movement of educational modernisation represented by the Anglo-American alphabet curriculum (Fensham, 2015), which was further accelerated by the successful launch of the USSR's Sputnik I in 1957. These factors strongly influenced science education in lower and upper secondary schools rather than elementary schools. This education movement in the West, represented by the alphabet curriculum, was influential in Japan from the late 1950s to the early 1970s (e.g., Isozaki, 2021) and was called *rika-kyouiku no gendaika* (the modernization of science education). Therefore, in 1969 and 1970, revisions to the course of study from elementary to upper secondary schools reflected the political agenda and international education movement. To organise appropriate curricula by considering the community and school, as well as the students' abilities, aptitude, and career paths, upper secondary schools provided *senmon-gakka* (specialised courses), such as science and mathematics and home economics.

For science education in this revision to the course of study for both lower and upper secondary schools, the main features were structuring "scientific concepts" and developing a scientific method (or scientific method<u>s</u>) by means of emphasising the "process of inquiry." Through the process of inquiry, students were expected to acquire structured scientific concepts and process skills. There were several criticisms of this revision, especially for lower and upper secondary science, such as an overload of contents and a lack of an authentic understanding of the Anglo-American alphabet curriculum (e.g., Isozaki, 2021). Consequently, Japan introduced the framework of the Anglo-American alphabet curriculum without an authentic and deep understanding of their philosophy, just like in the early Meiji era. Inquiry-based learning has been enhanced by every revision of the course of study since then and is still the style of learning that has characterised science education in Japan (e.g., Roth et al., 2016). The latest revision to the course of study, especially for upper secondary school, emphasises the term "inquiry" not only in science but also in other subjects. However, despite the advocation for inquiry-based learning, there are challenges. According to the National Assessment of Academic Ability conducted in 2022, the average score of lower secondary students is 49.7% (66.5% was the average score in the previous survey in 2018). The report concluded that there were challenges in examining the validity of others' ideas and in considering whether the experiment's design was appropriate, and then improving it. There was also evidence of improvement in the control of conditions in the design of experiments where issues had been observed in the past (National Institute for Education Policy Research [NIER],2022). Some content, for example, content relating to natural disasters and resources, which was taught to a certain extent previously, was rejected in this revision to the course of study because these concepts did not directly connect with the key scientific concepts.

The influence of the American and British projects on the course of study for elementary school science was limited compared with their influence on those of science education in lower and upper secondary schools. Science educators never ignore the Anglo-American alphabet curriculum in elementary school science and focused on analysing and investigating this curriculum through research rather than conducting the practice in classrooms. By contrast, the keyword for the course of study for elementary science was "problem-solving," which elementary teachers traditionally taught in classrooms (Nozoe & Isozaki, 2014).

A New Trend of Science Education

Japanese students have obtained higher scores than students from Western countries on international tests, such as the TIMSS and PISA. However, Japanese students have consistently been at the lowest levels in international tests in terms of their attitudes toward science and mathematics and their desire to pursue science and mathematics-related careers in the future. The percentage of students who like science decreased as they progressed to lower and upper secondary schools, as shown by the data of a longitudinal study on science and mathematics and a periodical survey of science and mathematics conducted by researchers of the NIER (e.g., Matsubara, 2001). Additionally, the National Institute of Science and Technology Policy (NISTEP, 2001) showed that the prevailing attitude toward science and technology and science literacy among the general public in Japan was lower than that in other developed countries.

According to the data on students admitted by faculties (Research Institute for Higher Education, Hiroshima University, n.d.), a slight decline in the percentage of students entering scientific faculties, excluding medicine and health, since around the time of the millennium can be observed. Changes in the compulsory elective requirement for science based on the revisions of the courses of study at the upper secondary school level have had an impact on the choice of faculties in university admissions. Under these circumstances, the Council for Science, Technology and Innovation of the Cabinet proposed the development of human resources in STEM fields in the second science and technology basic plan in 2001. Prior to that, the slogans "techno-nationalism" (Nakayama, 1991, p. 237) and "technological national-building" (Morris-Suzuki, 1994, p. 211), used by the government, had appeared in the 1980s. As mentioned in the previous section, this means that Japanese governments have traditionally recognised that human resource development in STEM fields is a crucial vehicle to national wealth and international competition as Japan has lacked natural and material resources since the Meiji era.

There was a shared sense of crisis, both politically and administratively, about the rika-banare, which can be translated to mean running away from learning science, disliking science, or a decrease in attendance at scientific faculties at universities or colleges, thereby leading to the urgent need to develop human resources in STEM fields. However, the authentic meaning should be translated as "running away from learning," as Sato (2000) argued. The newly reorganised Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched the SSH programme that oriented science for excellence in 2002. The present aims of SSH are to:

(1) Encourage innovative and enhanced science and mathematics curricula.
(2) Conduct joint research with universities to connect them with upper secondary schools.
(3) Promote initiatives to foster globalism.
(4) Develop teaching methods and materials to enhance creativity and originality (Japan Science and Technology Agency, n.d.).

The results of the SSH programme are expected to be reflected in the newly established subject, "Inquiry-Based Study of Science and Mathematics" or "The Period for Inquiry-Based Cross-Disciplinary Study," in upper secondary schools. Therefore, the newly revised course of study for upper secondary schools in 2018 enhances "inquiry." According to the MEXT, the intermediate assessment in Financial Year 2021 stated that while more than 40% of the 34 schools designated as SSH received at least a certain level of high evaluation, nearly half the schools needed further improvement (MEXT, 2022). Gender in science education is another important issue. For example, of the total number of students admitted by the engineering faculties in Japan, 99.3% were male and only 0.7% were female in 1970; 89.5% were male and 10.5% were female in 2000; and 84.5% were male and 15.5% were female in 2017. The proportion of female students in all engineering faculties at universities was 0.8% in 1970, 5% in 2000, and 4.8% in 2017 (Research Institute for Higher Education, Hiroshima University, n.d.).

The aims of the SSH programme are similar to the research on special/experiment classes for science education in the late WWII era. During that era, such specialised education was criticised as discriminatory; however, today, the hurdles to implementing SSH are lower due to social changes and the changing public attitudes toward science for excellence. Many programmes for the promotion of STEM education from primary to higher education levels are being implemented as both formal and informal science education in cooperation with industrial society and the government, involving independent agencies, such as the Japan Science and Technology Agency and the Japan Society for the Promotion of Science, and academia. The Keidanren (Japan Business Federation), which contributes to the self-sustaining development of the Japanese economy and the improvement of Japanese people's lives, often issues statements on education at each milestone.

DISCUSSION

Which Way Now from A Historical Perspective?

This paper has identified several historical characteristics of science education in Japan. First, Japan's centralised government has traditionally regarded education as a potent vehicle for building the nation and its economic and industrial growth. Therefore, under strong initiatives from the central government, the Ministry of Education has employed the purposes, teaching contents, and methods of subjects involving science since the mid-19th century. Consequently, Japan's education system has guaranteed learning opportunities and academic achievement for every child through laws and regulations involving the course of study and has worked to reduce regional differences. The decline in the motivation to learn, as seen in the so-called "running away from learning science," is an inevitable challenge faced today. Science has retained its position as an essential subject in the school curriculum from elementary to secondary education levels. Therefore, "Science for all" has been taken for granted in Japan; "all" targets every student who will be a scientifically literate citizen, including future scientists and engineers, from elementary to secondary education levels. However, the kind of science that should be provided at the secondary education level, especially upper secondary schools, has been an aporia in both the East and the West. In Japan, as mentioned above, every revision to the course of study may indicate one possible conclusion to that aporia.

Second, even though rika has always been influenced by the trends in science education in the West (primarily the UK, the US and Germany), since the mid-19th century, rika has encompassed Western science education and is characterised by a part of Japanese originality that can be recognised as alien to Western science education. Another way of describing it is "recontextualisation" (Isozaki, 2014). For example, unlike in the West, where science was defined as "Knowledge of the Law of Nature obtained by Observation, Experiment, and Reasoning" (Huxley, 1881, p. 10), shizen has traditionally been included as a keyword in *rika* objectives because of the Japanese emphasis on familiarity and harmony with *shizen*, as indicated by the view of nature. For example, in England, learning science in schools starts from grade 1, at the age of five; in Japan, there have been no science studies at the lower elementary school level for two-thirds of approximately 150 years of its history.

Third, the existing stress, which enhances teaching knowledge of/in science or pure science, sometimes limits the study of knowledge about science, such as the nature of science, the history of science, risk management and assessment, and how scientists justify their knowledge claims. However, even inquiries that face some challenges in lessons are in danger of succumbing to routine teaching due to overemphasis at the revision stage. Historically, the prevailing science curriculum has been socially influenced by both external and internal factors, such as the wars before WWII, Western science curricula, international and domestic tests, and social requirements for education.

Fourth, educational research and practice on science for excellence were conducted to educate future scientists and engineers in a few elementary and secondary schools for approximately three years, as mentioned above, around WWII, by the initiative of the Ministry of Education. Contrary to the situation in the period surrounding WWII, there have been few obstacles to organising a science curriculum that intends to enhance science for excellence, from around the millennium.

Science and STEM Education for All Japanese People?

It is difficult to answer which direction Japan's science education will take in the near future. However, if we recognise that Japan's science education has been recontextualised with Western science and that science education can be identified as historically and socially constructed, it would be possible to predict some of its future direction.

First, Japan's centralised government has regarded education as an essential vehicle for building the nation and its economic and industrial growth since Japan's modernisation in the second half of the 19th century. As if in response, the industrial society, especially in the post-WWII period, issued some statements and policies on education, which covered the primary to higher education levels. Second, educators (researchers, teachers and policymakers) have always kept a close eye on foreign educational trends involving the Organisation for Economic Co-operation and Development (OECD), especially in the West throughout history and in Asian countries in recent years, and have recontextualised them.

In recent times, STEM education has been recognised as an important factor for developing STEM-literate citizens, as well as for promoting the development of human resources in STEM fields as the key strategy of the nation-state's policy by both the government and industry within the context of globalisation. Japan's government has enhanced the promotion of STEAM, representing STEM combined with arts, such as the humanities and music, broadly comprising liberal arts. However, science will always remain an integral part of both STEAM and STEM education. As Drake and Burns (2004) argued, "the Japanese are turning to integrated curriculum" (p. 4), and using multidisciplinary or interdisciplinary approaches would be useful for implementing the "Inquiry-Based Study of Science and Mathematics" and "The Period for Inquiry-Based Cross-Disciplinary Study." Science teachers will collaboratively work with teachers of other subjects to implement STEAM education, considering Japan's educational tradition and context with reference to studies in other countries.

CONCLUSION

This study analysed the historical characteristics of science education in Japan from the perspective of "Science for all and for excellence." It aimed to answer the research question "Who is science education for?" There are, of course, self-imposed limitations. The historical profile may be different if analysed from a gender perspective or a science teacher and learner's perspective. It would be possible to identify more elaborate features using Briggs' (1972) approach, such as comparative history. However, to provide a more accurate portrayal using a limited number of words, the author explored the research question and employed the most suitable approach. Despite the limitations of the approach, the following conclusions could be drawn.

Historically, Japan has regarded education as an important vehicle for building the nation and for its economic and industrial growth since the mid-19th century during its modernization. Even if total public spending on primary to tertiary education as a percentage of total government expenditure is the lowest level in the world (OECD, 2021, p. 268), this traditional stance toward education, especially STEAM education, which aims to create scientifically literate citizens or STEAM-literate citizens, and develop more scientists and engineers, will be supported by Japan's government, industrial society and the public.

The Japanese will continue to develop *rika* that encompasses both homogeneous and heterogeneous Western science education, considering the trends in science education in the world. Consequently, while the policy of "Science for all" will be maintained in the near future, "Science for excellence" programmes, such as the SSH, may be extended in terms of the supply of future scientists and engineers, partly at the request of the industrial society in order to survive international economic competition based on scientific and technological innovation and to maintain Japan's international status.

One lesson from history is that science, as a part of liberal education, is provided for the individual well-being of scientifically literate citizens or STEAM-literate citizens, rather than for the benefit of the nation, as it is necessary for all students growing up in a society, whatever their career paths or aptitudes. Therefore, "Science for all and for excellence" should not be considered contradictory. Instead, "Science for excellence" should be recognised as encompassed by and a form or part of "for all." Finally, it should be added that science education, with such historical characteristics, is important for Japan's national strategy. Academic achievement among Japanese children is very high when compared to global levels, which can undoubtedly be attributed to the tireless efforts of science teachers.

The philosopher Santayana's (1953) comment, "Those who cannot remember the past are condemned to repeat it" (p. 82), has implications not only for historians of science education but also for policymakers. Isozaki and Pan (2016) stated that "to study the history of science education is no more and no less than to carefully describe, reflect and identify on its cultural background for the future" (p. 24). Consequently, the study on the history of science education in each country provides a good opportunity to reflect on what science educators (researchers, teachers and policymakers) in each country have always taken for granted. Despite its limitations, this study will be of interest not only to science researchers and teachers in Japan and overseas but also to all concerned with the dynamics of science curriculum change, including policymakers.

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