Secondary School Science Education for Whom?: An Historical Case Study from Japan

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Abstract: In many countries, secondary school science is no longer solely for those destined for careers in science, medicine or engineering and both boys and girls study biology, chemistry and physics. In Japan, secondary science has been studied by boys and girls as a compulsory subject since the establishment of the modern school system in the late 19th Century. However, although 'science for all' is becoming the norm, it appears that science is less popular with girls than it is with boys, and that lower-attaining students are not adequately catered for in Japan and elsewhere. In this paper, the author investigates gender issues in the secondary science curriculum and examines the curriculum for future scientists using a historical perspective and focusing on the case of Japan. An analysis of two historical issues, gender and the curriculum for future scientists, found that, firstly, the science curriculum needs to contain a clear statement of its aims, and, secondly, that the secondary science teacher is one of the most important factors influencing science teaching particularly for girls. ost important factors influencing science teaching especially for girls.

Key words: gender issues/ science for future scientists/ scientific literacy/ secondary science education

I. Introduction

In many countries, science in secondary schools is currently perceived as being 'in crisis'. On the other hand, should the science education in secondary schools for future scientists be any different than that for future citizens? Future scientists are also future citizens. What kind of science curriculum should we provide in secondary schools?

In this paper, the author investigates gender issues in the secondary science curriculum and the secondary curriculum for future scientists using a historical perspective, that is, the case of science teaching in Japan. Through an analysis of two historical issues of science curriculum design, the author discusses the questions of, "Who should the science education in secondary schools be for?", "What science should be taught?", and "What are the key issues for science teaching in the 21st century?"

II. Gender issues in secondary science education in Japan

1. Science education for girls before WWII

Academic research on gender issues in science education can be divided into a range of areas such textbook content (for example, Bennett, 2003). In this paper, the author employs a historical perspective to investigate gender issues through an analysis of factors such as curriculum, textbook design, teacher effects, and societal and cultural influences in secondary school science education.

1) Curriculum

In the Japanese school system, which aimed at a providing general education, science subjects were an essential component of the curriculum at the beginning of educational modernization in 1872. Secondary education before WWII, which was not compulsory, was classified into three types: viz., the middle school (secondary school for boys), the girls' high school, and the vocational, technical or commercial schools. As a result, since 1895 girls had studied science in secondary school before WWII. Table 1 shows the allocation of science subjects in the school curriculum.

Girls' High Schools spent less time on science than on Household Matter and Needlework. For example, in 1895, science occupied 5.7% of curriculum time compared with 18.3% allocated to Household

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Table 1
Science subjects in secondary curriculum for boys and girls

Middle School	%	Girls' High School	%
FY 1881	12.5		
FY 1886	4.3		
FY 1894	8.6	FY 1895	5.7
		FY 1899	4.5
FY 1901	9.6		6.3
FY 1911	10.7	FY 1908	6.3
FY 1919	12.1	FY 1920	8.9
FY 1931	12.1		
FY 1943	13.4		9.2

FY = fiscal year (Source: Matsuno & Isozaki, 2004)

Matter and Needlework. In 1920, science occupied 8.9% of the curriculum and Household and Needlework occupied 18.6%. Of course, one reason for these differences is the difference in school length for each girls' high school (4 years, and 3 or 5 years) and middle school (5 years).

Science in middle school (until 1931) was composed of two subjects, 'Natural History' (botany, zoology, mineralogy (including geology) and physiology and hygiene) and 'Physics and Chemistry'. On the other hand, girls' high school science was not sub-divided although there was some overlap in content with middle school science. The name 'Science' had only been used in elementary school and girls' high School until 1931 when the 'General Science' was introduced into the middle school science curriculum.

The President of the Imperial University of Tokyo, and some-time Minister of Education in Japan, Kikuchi (1909: 276) pointed out that the standards of the syllabus for girls' high schools, in almost all subjects, were lower than those in middle schools. He also noted that even where syllabuses had the same wording, giving the same items and directions, there were differences between the types of school owing to the number of hours given to that subject; moreover, there were difference in attainment between boys and girls.

2) Textbook design

Isozaki (1988) and Matsuno & Isozaki (2004) analyzed Mineralogy and Chemistry textbooks written for girl's high school and middle school. In order to look at gender issues, we examined books that were written by the same authors and published by the same companies. In general, girls' high school textbooks emphasized science in the context of everyday life. In contrast, middle school textbooks tended to emphasize academic or pure science. Girls' high school textbooks also contained more figures and tables than did middle school textbooks. One textbook for girls had illustrations that focused on the contribution of female scientists, for example, Marie Curie and Madame Lavoisier. It is worthwhile to point out that in practice, there were a few cases where science teachers at girls' high school used middle school textbooks for their pupils and few male academics wrote girls' textbooks with similar contents to boys' textbooks.

In 1918, the Ministry of Education established the syllabi of physics and chemistry experiments for middle school and normal school, but not for girls' high schools. The syllabi were influenced by, and based on, the heuristic method advocated by Professor H. E. Armstrong in the UK. The syllabi included practical work using laboratory manuals. The syllabi influenced similar developments, albeit limited, in girls' high schools. Some girls' high schools constructed science laboratories and made laboratory manuals similar to those found in middle schools (although they were limited by the reduced budget of the girls' high school).

3) Science teachers

The main route to become a middle school or a girls' high school teacher was to graduate from a higher normal school or a university. The higher normal school was divided by gender. Graduated students from higher normal schools for boys could teach in both middle and girls' high schools. However, graduate students from a higher normal school for girls could only teach in girls' high schools. Furthermore access to higher institutes was very limited for girls before WWII.

4) Societal and cultural influences

The object of middle school was stated in the Ordinance on Middle School as "to give a higher general education necessary for men", that is, a general education necessary for those who were to be of middle or higher social standing. On the other hand, the object of the girls' high school was stated in *the Imperial Ordinance on Girl's High School* "to give higher general education necessary for women". These aims are based on utilitarian and cultural arguments (Millar, 1996; Osborne, 2000).

Before WWII, and especially from the mid 19th century to the early 20th century, girls' education was based on the assumption that women got married and that the object of schooling, therefore, was to prepare a girl to become a 'good wife and a wise mother' (ryousai-kenbo in Japanese). Kikuchi (1909) explained the position of women in society as follows:

> We hold that women are born to matrimony, that their natural vocation is to become wives and wise mothers. Our idea of womanhood is 'good wife and wise mother.' We consider home to be the woman's sphere. 'Man works outside and woman helps at home' is our maxim. (Kikuchi, 268)

This maxim influenced the Japanese educational system, including science education, for many years.

2. Science education for girls after WWII

1) Curriculum, textbook and teachers

In 1947, the Fundamental Law of Education was enacted. The law set forth the basic national aims and principles of education, such as equal opportunity of education, nine-year compulsory education (6 years of elementary school and 3 years of lower secondary school), co-education and prohibition against partisan political education. Therefore, nobody, without exception, has been allowed to skip a school year as happened before WWII.

The objective and content of each course and subject has been stipulated under the Course of Study established pursuant to laws and ordinances. The Course of Study is similar to national standards or the national curriculum in other countries, and it has been revised approximately every ten years. In general, boys and girls study the same science content laid down in the Course of Study. They use textbooks inspected and authorized by the Ministry of Education at each stage of schooling. Institutionally and apparently, lower and upper secondary schools pupils generally study the same content. The teacher education system has changed dramatically and many higher education institutes opened their doors to girls after WWII. Other gender issues in science education, however, have arisen since the 1950s.

2) Attitudes to science

Boys' and girls' attitudes to science are an issue in secondary education in Japan. As with other research on gender issues in western countries (for example, Sjøberg 2000), the results of a survey conducted by the new Ministry of Education (MEXT: reorganized since 2001) and published by the National Institute for Educational Policy Research (2004) found generally negative attitudes to science (See Table 2). These studies and surveys have consistently demonstrated that boys show a preference for studying physics and chemistry, whereas girls prefer biology.

3) Societal and cultural influences

Japanese economic development has led to rapid social changes with respect to people's life-styles. The more industrialised and work-focused society has needed greater human resources. The traditional ideas and notions about girls' education have gradually changed with time. However, there is some evidence that traditional gendered ideas and notions still influence career choice in science and technology fields. One issue relates to the choice of area of study at university, the other relates to career paths in science

Table 2
Pupils' attitudes to science in upper secondary schools (Question: I like studying Physics)

	Physics		Chemistry		Biology		Earth Science	
	agree	disagree	agree	disagree	agree	disagree	agree	disagree
Boys	42.1(%)	53.6(%)	34.4(%)	60.7(%)	39.5(%)	53.3(%)	45.0(%)	49.0(%)
Girls	24.5(%)	71.8(%)	23.9(%)	72.9(%)	41.9(%)	53.6(%)	39.6(%)	56.1(%)

Note: 'Agree' includes 'agree, rather than otherwise'. 'Disagree' includes 'disagree, rather than otherwise' (Source: NIER, 2004) and technology.

An international comparison (OECD, 2005, 2006) of academic levels shows that the proportion of women studying natural sciences and engineering fields in Japan was lower than in other OECD countries. In contrast, the proportion of women studying cultural sciences was the same as in other OECD countries. The survey conducted by the European Commission (2006) identifies two key facts relating to women researchers' careers. Firstly, the proportion of female researchers was only 12% in 2003, the lowest of any country in the survey (in the European Union, for example, the figure was 29%). Secondly, the presence of women across the sectors (higher education, government and also business enterprise) revealed some recurrent patterns of under-representation. In every sector, Japan was on the lowest rank. This under-representation of women in research may result from different career models as well as historical and current discriminations. The reasons for the lower proportions of female researchers were identified by women themselves and by male researchers as follows: the most significant reason was 'family matter, for example, childbirth, child care and nursing care' for both genders. The second reason identified by women was 'disadvantage for women on evaluation, promotion, and treatment'. Men, however, chose a different second reason: 'few women want to do research' (MEXT, 2006).

In terms of studying science, the national research data provides the following context: throughout Japan, in the elementary school age range, pupil enthusiasm for science remains higher than for other school subjects. During secondary schooling, though, enthusiasm falls off sharply compared to other school subjects. Many pupils agree that science is important, but they feel that it is 'not for them' (NIER, 2004; NIER, 2005). International data (TIMSS 2003) for 8th grade pupils shows that, in terms of the enjoyment of learning science, Japan is in the bottom group although, in contrast pupils get higher attainment scores (Martin *et al.* 2004: 170). The SAS (Science and Scientist) study shows similar results to the TIMSS 2003 study. Sjøberg (2000) stated that 'Japanese pupils indicate a remarkably low interest in science, in particular the girls' (Sjøberg, 2000: 174). Furthermore, Japanese pupils' confidence in learning science is at the lowest level among countries taking part in the international survey.

However, we have to recognize that it is hard to judge whether pupils are able to provide a realistic assessment of their own learning, and/or whether the data reflects their positive attitudes towards learning science. In general, the Japanese students' performance in international comparisons, such as TIMSS (Martin *et al.,* 2004) and PISA 2003 (OECD, 2003) has demonstrated that in all science subjects, boys have scored more highly than girls, though the difference is not statistically significant. It is possible that differences in ability may be negligible and in no way account for the differences in attainment. However, we have to pay attention to the fact that an international comparative survey targeting adults (18 or over) regarding their degree of understanding of basic concepts in science and technology showed that Japanese adults' literacy was at a low level among the 17 countries studies(MEXT, 2003).

The gender issues extant before WWII resulted from societal and cultural influences, for example, the idea of women as being 'good wife and wise mother' and on the hypothesis that spatial differences were genetic in origin. These societal and cultural factors still influences girls' career paths, although not as strongly as was the case before WWII. After WWII, the gender differences have gradually shifted to differences in attitudes to science. Of course, the teacher effects still hold true, at large, in Japan, and will be discussed later.

Ⅲ. Science for future scientists

1. Special Science Education Programme 'Experimental class for science education', 1945-7

During the long history of science education in Japan, there was only one time when a special science education programme (an experimental class) was established in order to educate future scientists and engineers. Of course, before then, there was a grade-skipping system of elementary and middle schools, where some able pupils were allowed to skip ordinary courses to study advanced courses in higher stage schools. From January 1945 to March 1947, with the initiative of the Ministry of Education, a special science education programme had been organized at the national elementary schools (upper grades) and the middle schools attached to higher normal schools in Tokyo, Hiroshima and Kanazawa, and the national elementary schools and Girl's High School attached to Tokyo Girls' Higher Normal School and two national elementary schools and prefectural middle schools in Kyoto and Kobe contacted and managed by the Imperial University of Kyoto.

The special science education programme was based on the proposal adopted in the Imperial Diet on 7th September 1944. The original object of this programme was to expedite the military technology in the medium and long term, however, the explicitly stated object in a document of the Ministry of Education in the final stage was 'to research how to implement an intensive science curriculum, aiming to educate and train the gifted pupils to accelerate their progress in science and technology in Japan' (Kosaka, 2006; 20-21). As WWII had just ended, the object of this programme was changed slightly: the object of this curriculum in terms of educating future scientists and engineers was, however, the same as the old version. The programme was based on economic and national arguments (Millar, 1996; Osborne, 2000).

The admission methods for selecting entrants were different according to every higher normal school, girl's higher normal school and the Imperial University's policy, which usually included achievement tests, aptitude tests, mental ability tests, intelligence tests, references and interviews. Some applicants were considered in terms of their inheritance.

Generally speaking, every curriculum was naturally oriented towards science and mathematics, especially physical sciences rather than biological science, however, Japanese, History and Geography and English were allotted a considerable time compared with the ordinary curriculum. Some schools' curricula included engineering and technology. Under these curricula, middle school science teachers and professors of higher institutes taught advanced level classes in science and mathematics, for example, 'old' high school level (now the first and second year level of higher institute). Their teachings emphasized practical work including research studies by pupils. It is said that nevertheless during war, special science education programme proceeded with a liberal atmosphere. Pupils had also opportunities to have lectures and practical works at higher institutes.

Pupils were impressed and influenced throughout this programme and some eventually became scientists and engineers. However, not as many pupils of the girls' high schools attached to Tokyo Higher Normal School for Girls went to scientific higher institutes, compared with other middle school pupils. A culture existed in which many girls' families did not want their children to go to scientific higher institutes (Kosaka, 2006: 101)

Iwatsubo (2005) identified some points about gifted students' education:

1. It is very important for gifted students to be provided with human sciences courses as well as intensive advanced natural science courses, since the greatness of the works in science and technology depends on how he or she researches the ability of universally recognizing and reflecting world.
2. The students used to belong to experimental class for science education (note: special science education programme) have made afterwards remarkable contributions to the field of not only science and technology but human and social sciences, which suggests that intensive science education generally causes to cultivate creative and challenging minds of students. When gifted students should select their professionals is also important problem to meet the sound development of early stage education of our country.
(Iwatsubo, 2005: abstract in English)

As Iwatsubo pointed out, special science education programme had provided a model of when and how to offer those programmes and also a pedagogy on science for gifted children. However, we must note that some graduated students and some professors who joined the projects and managed the programme were critical, complaining that the programme involved too much cramming and lacked suitable teachers and appropriate teaching strategies, etc. It is difficult to evaluate the outcome of this programme due to its short lifetime and the small numbers of schools involved.

2. New programmes since 2002 'Science Literacy Enhancing Initiatives'

After WWII, basic principles for education in Japan were provided by laws such as all people shall have the right to receive an equal education correspondent to their abilities. This newly-established system has probably contributed greatly to raising standards of literacy and to develop the industrial and economic power of Japan by providing a well-educated work force. However, Ouchi (1994) who took 'experimental class' in Kyoto, argued that such uniform education must have hampered the development of precious individual talents particularly in science. Such opinions have been almost ignored for many years (Ouchi, 1994: 126).

In 2002, the Ministry of Education adopted the 'Science Literacy Enhancing Initiatives' programmes to implement comprehensive policies for the support and promotion of efforts in mathematics, science and technology education. The main components of this programme, targeting upper secondary schools, are the Super Science High Schools (SSHs). There are, however, other significant programmes such as the Science Partnership Programme (SPP) and the Rika Daisuki School.

The SSHs, which are designated by the Ministry of Education, give their students enriched mathematics and science curricula in order to encourage and develop future scientists and engineers. A basic objective of the SSHs is to foster students' interest and enjoyment in mathematics, science and technology and also to enhance their personalities and abilities. The SSHs have attempted to cooperate effectively with universities and research institutes, etc. (MEXT, 2003). In FY 2006 there are 99 SSHs designated by the Ministry of Education.

Comparing the special science education programme and the SSHs project, there appear to be some similarities, as follows:

1. Both programmes are designated by the Ministry of Education and schools can organize intensive mathematics and science curricula beyond the syllabi and the course of study for the ordinary curriculum.
2. Human and social science subjects are allotted a considerable amount of timetabled time by comparison with ordinary curricula.
3. Pupils study aspects of science and mathematics to an advanced level. They can have lectures from university professors, and schools cooperate with universities and research institutes.

IV. Discussion

1. Gender and secondary science curriculum: teacher influences?

To say that science, especially school science, has been widely perceived as masculine is no longer considered controversial (Hodson, 1998: 104). The debate has centred on the extent to which this perception is due to the way that school science is taught to pupils, as well as the perception that science, and/or school science is inherently masculine. In terms of the perceived masculinity of science, Kelly (1987) has pointed out following that:

> There are at least four distinct senses in which it can be argued that science is masculine. The most obvious in terms of numbers - who studies science at school, who teaches it, who is recognized as a scientist. Secondly, there is packaging of science, the way it is presented, the examples and applications that are stressed. Thirdly, there are the classroom behaviours and interactions whereby elements of masculinity and femininity developed in out-of school contexts are transformed in such a way as to establish science as a male preserve. And finally there is the suggestion that the type of thinking commonly labelled scientific embodies an intrinsically masculine world view.
> (Kelly, 1987: 66)

In line with both Kelly and Murphy (2000), Deem (1978: 22) noted that:

schools have many subtle ways of indicating to children which aspects of culture they are supposed to absorb – and which they are not – whether by means of streaming pupils by ability, or in some other manner.

Who teaches science in secondary school would be one of the factors which might influence a girl's choice of science subjects and her future career. As Scaife (1998) points out, teachers do occupy positions of considerable influence and autonomy within their own classrooms, even if children arrive at school with well-established notions of gender.

Table 3
Percentage of male and female science teachers

Subject	Female	Male
Physics IB	3.2%	96.8%
Chemistry IB	11.8%	88.2%
Biology IB	18.1%	81.9%
Earth Science IB	5.2%	94.8%
Japanese I	40.6%	59.4%

Note: 'IB' is academic and pure science rather than 'IA' which focuses more on science in everyday life (Source: NIE, 2004)

A national survey in FY 2002 by the Japanese Ministry of Education, examined the numbers of female and male science teachers in upper secondary schools (see Table 3).

There is other data to support the importance of teacher influence on students. In a survey conducted by the Ministry of Education, respondents were asked to name the person or thing that had an effect on their choice of researcher as a career; 20% of respondents selected 'teacher in elementary, lower secondary, or upper secondary school, followed by 'science textbook, at 6.1% (MEXT, 2003).

In general, girls have chosen to study biology rather than physics and more boys than girls have opted to take physical sciences. Therefore, it is necessary to investigate how closely teacher influence is related to girls' selections of science subjects in upper secondary school in terms of Bourdieu's ideas of cultural reproduction. We need to make a project similar to that of GIST (Girls into Science and Technology) in the UK and MiNT (Mädchen in Naturwissensschaften unt Technik) in Germany, both of which increased enthusiasm for science and showed girls pathways to scientific careers. Recently, some universities and the independent agencies in Japan give some programmes to enhance and improve girls' interest in science and technology fields financial supported by the Ministry of Education.

2. Secondary science for all or for excellence: which way now?

After WWII, lower secondary school (7th to 9th grade) became compulsory and all pupils studied the same science contents. However, for upper secondary school (10th to 12th grade) school has been not compulsory. Since the 1970s, all pupils of upper secondary schools have had to study science, either as separate sciences or as balanced science. Before then, only separate science subjects were taught. In a sense, balanced science (general science, integrated science and etc.) has been presented as a 'medley' from a whole area of science since then, even if we agreed with the idea of balanced science. In contrast, separate sciences have tended to be 'pure' and 'academic' science since the beginning of secondary science teaching in Japan. There has been relatively little emphasis on discussion or analysis of any of the scientific issues that permeate contemporary life. Traditionally, school science has been presented as a body of knowledge which is value-free and objective, with a lack of context relevance to the future needs of young people as citizens. It appears that teaching separate sciences in upper secondary schools successfully winnowed out science-talented pupils from all pupils in secondary schools. Therefore, pupils show less interest in studying science as indicated above in Table 2 and by the other data mentioned earlier.

In recent years, the evidence related to school science seems to indicate a growing tension between the science studied in school and the science portrayed in the media. Science can no longer be detached from the values and priorities of the advanced scientific and technological society in which it is embedded. Therefore, there seems to be a gap between the needs of future scientists and engineers and the needs of well informed citizens. As Millar (1996) pointed out, many of problems of the science curriculum for secondary school stem from the fact that it is trying to do two different jobs. On the one hand, the science curriculum aims to help all pupils attain and improve 'scientific literacy'; on the other hand, it also aims to provide the first steps for those who may want to study science at a more advanced level.

Jenkins (2000) advocated the need to change the aims of science education, and argued that the 'aims will need to become more student-centred, reflecting what studying science can do for the student rather what the student may eventually be able to contribute to science.'(Jenkins, 2000: 223) Such science education should be based on cultural and democratic arguments (Millar, 1996; Osborne, 2000). The next step we have to take is to ensure that pupils experience science 'for all', at the upper secondary school level. School science should be compulsory and it should differ from the traditional former offer and be designed to emphasize scientific literacy – the understanding and skills which all pupils, both boys and girls, need as future citizens in advanced scientific and technological, and also democratic and uncertain societies. Of course, it is important to provide sound foundations for more advanced study for pupils who want to follow a scientific career route and for society that requires a steadily supply of well educated and qualified scientists and engineers. Can a science education at upper secondary school be designed to provide a worthwhile and satisfying experience for the majority of pupils who are future citizens, but not future scientists or engineers? After studying balanced science to enhance scientific literacy, elective separate sciences should be offered, and also new science programmes should continue to be developed and guaranteed for pupils who are eager and enthusiastic to study science at a more advanced level. The caveat here is that the requirement for new science programmes should not distort balanced science which enhances scientific literacy.

V. Conclusion

Secondary science for whom? Historically, science has occupied a central position in the school curriculum: all pupils in secondary schools, viz. middle school and girls' high schools (before WWII), and lower and upper secondary school (after WWII) have studied science since the beginning of modernized education in Japan. Although different sciences in terms of different teaching objectives and content were delivered for boys and girls before WWII, all pupils in secondary schools have studied science as compulsory.

Through analysis of two historical issues, viz. gender and intensive science curriculum, it is evident that, firstly, the science curriculum needs to contain a clear statement of its aims in order to make clear why pupils should learn science in secondary schools, secondly, that the science teacher is one of the most important factors influencing science teaching. One of the factors attributed to the success of Finish pupils in international comparison tests is also highly qualified teachers (Väliärvi *et al.*, 2002).

As I have described in the Discussion section, teachers' influence is one of the most important influence on girls' attitude to science. When we think about taking action for future generations, we need to recognize not only the necessity of designing and making the secondary science curriculum accessible to all pupils - boys and girls - irrespective of their background and socio-economic status, but also the necessity of changing the teacher education curriculum.

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