School Mathematics and Gender：from the progress of related studies and practices.

Hanako Senuma

In this paper I describe the latest trends and prospects, including changes over the past 20 to 30 years, concerning mathematics and gender with regard to the following three topics. 1) Trends in gender differences in mathematics seen through research into mathematical education research and international academic ability surveys; 2) trends in mathematics textbooks; and 3) the materialization of methods to create an awareness of the unperceived.

The main content is as follows. 1) The issues of gender in mathematics education has become a topic for discussion in the equity of nations and culture, social class and ethnicity. Gender differences in marks for mathematics are becoming smaller at elementary and lower secondary schools, but there is a difference between male and female attitudes to the subject. The number of female mathematics teachers at lower secondary schools is still low. 2) Mathematics textbooks are shifting towards a context of independent and interactive deep learning, improvements are being made in the illustrations regarding male/female ratios and roles, and there are textbooks in which females appear in mini-essays doing work that uses mathematics. 3) There is hope that the Educational Material for Instructors released in March 2021 by the Gender Equality Bureau, Cabinet Office, will serve as a step forward in encouraging future improvements.

Keywords: Mathematics education, gender, gender differences, value of mathematics, the real world and mathematics

Introduction

Funded by the KAKENHI Grants-in-Aid for Scientific Research I am conducting for the second time, and after a period of around twenty years, research into mathematics and gender.[1] This paper takes a brief look back on 20 years ago, after which I wish to cover the following three latest trends and prospects.

- The direction of mathematics research education, and trends in gender differences regarding mathematics seen through international academic ability surveys.
- Trends in mathematics textbooks.
- The materialization of methods to create an awareness of the unperceived.

1. What was thought and understood 20 years ago

(1) Why “mathematics and gender?”

Despite living in an age of gender equality and individualization, there are some sectors of society in which the social image and notion that "mathematics is for men" stubbornly persists among some people, and this has a direct and indirect harmful influence on pupils and students. Why is it that so many girls enjoyed arithmetic at elementary school but faced with gradually worsening mathematics results grow to dislike the subject, and do not elect to take mathematics courses at upper secondary school? It was found that some girls were instructed that they didn't have to take mathematics at upper secondary school because they wouldn't need it to get into university, and that in some cases mathematics teachers were unconsciously asking mainly boys to answer questions during mathematics classes. Instead of gender discrimination, we should aim to make mathematics an attractive subject in which any pupil or student can become immersed.

(2) **There are some countries in which there are many female mathematics teachers, girls' mathematics results are good, and many of them complete mathematics courses**

One particular feature that stood out in Japan was the image that lower secondary school mathematics teachers are men. In 1995 the International Association for the Evaluation of Educational Achievement (IEA) Trends in International Mathematics and Science Study (hereinafter abbreviated to TIMSS) found that the percentage of lower secondary school students in Japan who had received mathematics tuition from female teachers was just 28%, while the international average level was high, at 53%.

The next issue is academic achievement. It was thought that the reason women are unable to be active in mathematics education is environment rather than ability. At the 8th International Conference on Mathematics Education (ICME8), held in Spain in 1996, cases reported on included one from the UK that stated "In recent years when mathematics tests are held the boys cannot answer the questions and this is causing trouble. The problem is the mathematics education of boys," while a report from Australia revealed that because a state policy had introduced an enrichment program aimed at females the academic performance of boys in upper secondary school graduation examinations had become worse than that of girls.

With regard to the enrollment of upper secondary school mathematics courses the US Department of Education's 1997 Condition of Education reported that with the exception of algebra I, algebra II, geometry and trigonometry, in other words "calculus," more girls than boys completed enrolled courses in every other mathematics subject.

(3) **There is a large gender difference in attitudes**

Many countries had large gender differences in attitudes. In answer to the self-evaluation question placed to second grade lower secondary school students of "what are your mathematics results like?" out of 39 countries the results were higher for boys in 18 but for girls in only one.

(4) Governmental and school initiatives

There were cases of initiatives taken in various countries by governments, researchers and schools. In Australia various initiatives were taken such as asking females who had carved out careers in various occupations to talk about how important mathematics was in their work, and TV and radio commercials spreading the message that "mathematics diversifies your employment options."

(5) mathematics textbooks weakly linked to culture and history

If the image that mathematics is a male subject becomes entrenched in society there is a possibility that female students will lose their motivation, and it is thus that in nations such as Sweden, Germany and Australia attempts have been made to depict males and females in equivalent ratios in the photographs and illustrations shown in mathematics textbooks. Japanese textbooks tended to be dominated by diagrams and graphs, figures that represent mathematics themselves, and they contained few photographs or illustrations reflecting the real world. The mixed male and female illustrations in some textbooks for fifth grade elementary pupils and older declined and male illustrations increased. Some even had fixed gender-based role illustrations such as boy softball pitchers in the "statistics" section, and girls making salad dressings in the "ratio" sections.

(6) Value of mathematics

Christine Keitel, vice-president of the Free University of Berlin saw the issue of mathematics and gender as a question of social justice and democracy, saying: "Looking at women's issues, the problem of general mathematics education on the same level as for that of men emerges. The perspectives of other disciplines and subjects, debate over the appropriateness and trustworthiness of mathematical models, history, common sense and mathematics, occupations in the future, cooperation and competition, and male and female participation should be encouraged." Shigeru Shimada, a former professor at Tokyo University of Science said that: "The preliminary mathematics text books produced in the first half of the Showa era (1926-1989) for girls' schools were not just trimmed down versions of the boys' textbooks but were created under independent thinking (for example the use of kimono obi (belt) designs as an attempt to introduce the thinking of group theory and so on.)" Emphasizing the idea that "students construct mathematics," after solving a problem students started to write out themselves conclusions about the problem's character and theorem.

Through these lectures it was shown that mathematics consists of children and students learning through the creation of mathematical models, includes relationships between history, culture and the

real world and relationships between other textbooks and occupations. A set of values in which not merely competition but also cooperation is vital when studying mathematics was also shown.

In the following chapters I will focus on the mathematics education trends. As the Educational Material for Instructors released in March 2021 by the Cabinet Office's Gender Equality Bureau and discussed in Chapter 4 covers lower secondary schools, I look mainly at lower secondary school mathematics, while referring to elementary schools and upper secondary schools where necessary.

2. Trends in research into mathematics education, and gender difference changes in mathematics seen through international academic ability surveys

(1) Trends in gender research as a part of mathematics education research

Hino et al. who are co-researchers of this Kakenhi research project analyzed the trends in mathematics education (Hino, Kimura, 2019). They analyzed *First, Second and Third International Handbook of Mathematics Education* (1996, 2003, 2013), *National Council of Teachers of Mathematics (NCTM) Handbook of Research on Mathematics Teaching and Learning* (1992, 2003, 2017), and academic papers published by the International Group for the Psychology of Mathematics Education (IGPME) between 1990 and 2018. Their analysis found on one hand that over the past 25 years there has been an improvement in female participation with more girls taking mathematics courses and pursuing occupations in science, technology, engineering and mathematics (STEM) fields, and the calls for gender research are less vociferous. On the other hand, however, they found that the gender research trend is still continuing in the fields of psychology and sociology, and that the various gender issues in mathematics education are deeply embeded in other problem such as social impediments and inequities involving nationality, culture, class, ethnicity and socioeconomic status.

At the 12th International Conference on Mathematics Education (ICME) held in Seoul in 2012, there was a subcommittee on "gender and mathematics education, and at the 13th Conference held in Hamburg in 2016, and the 14th Conference held in Shanghai in 2021, the gender problem was included in the agenda of the "equity in mathematics education" subcommittee, and their findings matched those of Hino et al. It should be noted that the chairperson of the 13th conference was a female, and there was a large presence of women mathematics educators among overseas participants, quite different from the situation in Japan.

(2) Arithmetic scores have improved among Japanese elementary and lower secondary school pupils, and the gender gap is closing

Mathematics is considered to be the most universal among all the subjects taught at schools. Mathematics was the subject chosen for the first International Association for the Evaluation of

Educational Achievement (IEA) conducted in 1964. From the first evaluation onwards gender differences in mathematics performance, interest, attitude, and performance and interest in the subject at coeducational and single-sex schools have been published.

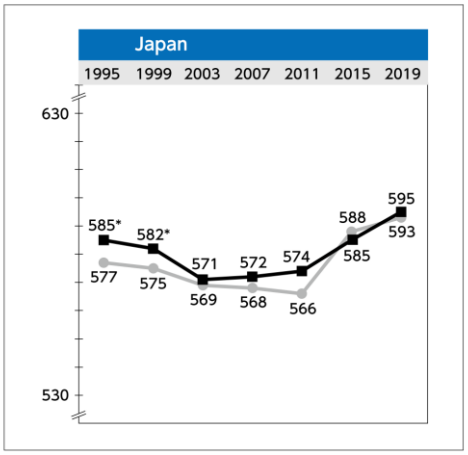

Fig. 1 TIMSS mathematics scores and gender difference (■ Males, ● Females)
(Results for Japanese second grade lower secondary school students from 1995 to 2019)
Note: The asterisks in the chart (1995 and 1999) indicate that the height of the boys' scores compared to the girls' scores was statistically significant. From 2003 to 2019 there has been no statistically significant difference between the mathematics scores of second grade lower secondary school students. The scores for both sexes in 2019 were higher than in 2003. The chart is based on the international report of Mullis, I. V. S. et al., 2020.

Subsequently, although it can be said that the analyses perspectives have differed somewhat, an international gender difference has been continuously reported. The IEA's TIMSS mathematics scores and gender difference results from 1995 to 2019 are as displayed in Fig.1. There is no gender difference in the mathematics scores of second grade lower secondary school students from 2003 to 2019. Likewise, there was a significant statistical difference between the scores of fourth grade elementary school pupils in 1995, but this difference has subsequently ceased.

On the other hand the aspects of the scores in the "mathematics literacy" section of the Program for International Student Assessment (PISA), conducted on 15-year-olds every three years since 2000 by the Organization for Economic Cooperation and Development (OECD), are different. In the years 2006, 2012 and 2018 there was a significant statistical difference in the Japanese students' scores, with the boys' scores being higher in all cases. The cause of these differences is unknown.

(3) There is a gender difference in attitudes

Using the TIMMS data up to 2015 and the PISA data up to 2018 it is possible to conduct gender difference analyses over the Internet[22] without the need for statistical software packages such as SPSS. In the 2015 TIMSS survey the male Japanese second grade lower secondary school students were more positive in responding "I would like a job that involves using mathematics." The PISA survey investigated attitudes to mathematics twice, in 2003 and 2012. A gender difference among 15-year-olds was observed in both surveys, with a large number of Japanese girls feeling unconfident and anxious. Making mathematics enjoyable, removing feelings of anxiety and endowing students with confidence is an issue in the way that mathematics instruction is conducted.

(4) **There are still few female mathematics teachers at lower secondary schools in Japan**

I had anticipated that currently the proportion of female mathematics teachers was probably rising, but the ratio is still low. Fig. 2 shows the proportion of mathematics teachers by gender recorded in the TIMSS survey (2019, second grade lower secondary school students).[3] The percentage of students receiving mathematics instruction from female teachers in Japan was 22%, the lowest rate among all the 39 countries participating. The international average was 60%, while in Lithuania it was 95%, in the US 68%, in England 50%, and in East Asia it was 72% in South Korea, 42% in Hong Kong and 41% in Taiwan. If there are many female teachers around one, it is no doubt likely that the assumption that "mathematics is for men" will dissipate. An outstanding issues is how to increase the number of girl students aiming to become mathematics teachers at university departments of education, science, engineering and informatics, the departments from which it is possible to obtain a mathematics teacher license.

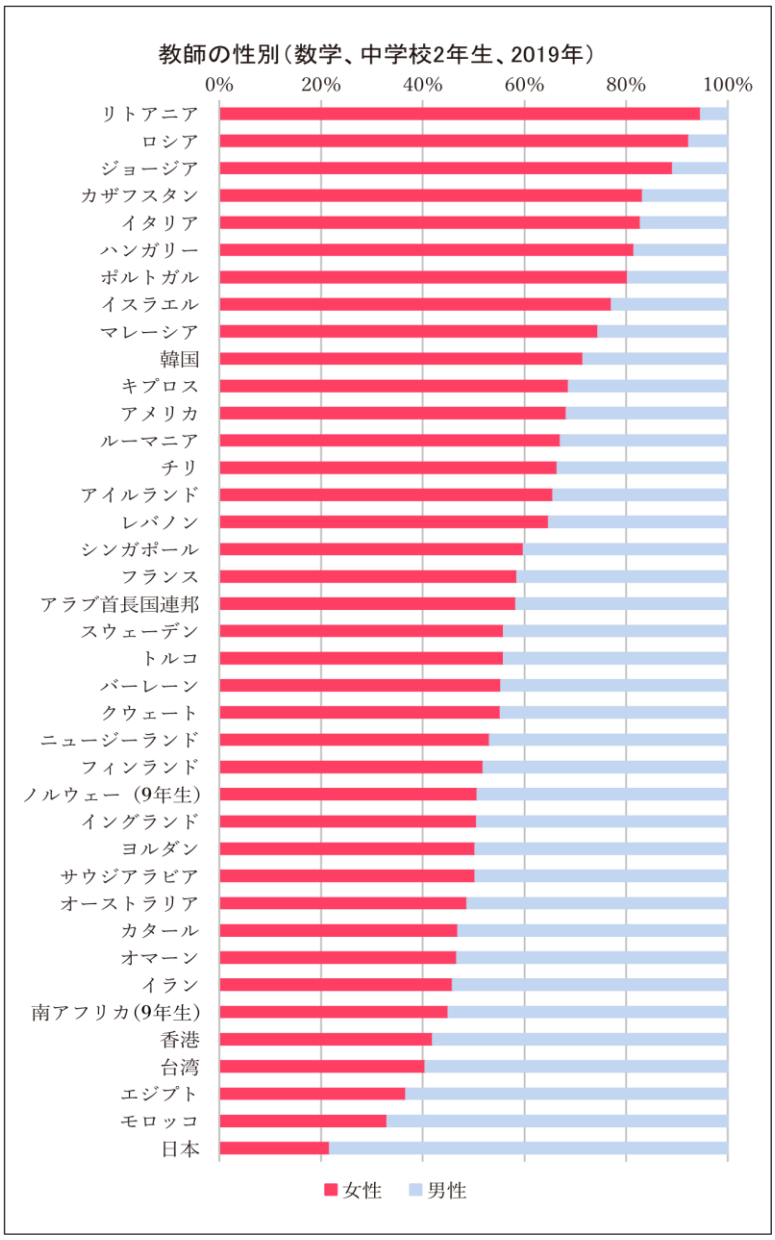

Fig. 2 Mathematics teachers' gender in the TIMSS survey (second grade lower secondary school teachers, 2019)

Teacher gender (mathematics, second grade lower secondary school teachers, 2019)

Lithuania

Russia

Georgia

Kazakhstan

Italy

Hungary
Portugal
Israel
Malaysia
South Korea
Cyprus
US
Rumania
Chile
Ireland
Lebanon
Singapore
France
UAE
Sweden
Turkey
Bahrain
Kuwait
New Zealand
Finland
Norway (9th grade)
UK
Jordan
Saudi Arabia
Australia
Qatar
Oman
Iran
South Africa (9th grade)
Hong Kong
Taiwan
Egypt
Morocco
Japan

Women

Men

Note: In the TIMSS survey the students were chosen by sampling. The teachers are the teachers of the students chosen by sampling, and the data shown in Fig. 2 was created by converting the proportion of students undergoing instruction. The proportion of women teachers in Japan was the lowest among all 39 participant countries.

Created by the author based on the data on p.4 of the T19_G8_MAT_TeacherAlmanac in the Data Almanacs at the following site: https://timss2019.org/international-database/

3. Latest trends in mathematics text books

(1) Revision of the Basic Act on Education in the background of national curriculum guidelines

In Japan the objectives and content of the textbooks studied at elementary, junior high and upper secondary schools are stipulated by the national curriculum guidelines, revised about once every ten years. The latest revisions were made over the years 2017 and 2018, and have or will be become completely implemented at elementary schools over the 2020 school year, lower secondary schools over the 2021 school year and upper secondary schools over the 2022 school year. The national curriculum guidelines for mathematics do not mention gender equity.

However, “equality between men and women” was added to Article 2 (“Objectives of Education”) of the revised Basic Act on Education (2006), the law that is the background to the national curriculum guidelines. Subsequently, at elementary schools from the 2011 school year and at lower secondary schools from the school year 2012, all the arithmetic or mathematics textbooks state gender equality in the editorial statements etc. submitted by the publishers to the Ministry of Education, Culture, Sports, Science and Technology (MEXT). It is to be hoped that ten or so years having passed since these changes a positive impact is being exerted upon the children and students who have studied these textbooks.

(2) Proportion and role of boys and girls featured in textbooks

In the past differences were observed in the degree of portrayal and stereotyped role divisions among boys and girls featured in illustrations in mathematics textbooks (Hazama & Senuma, 1995). In this research I have analyzed textbooks published in 2020 and 2021 (arithmetic textbooks published by six publishers, and lower secondary school mathematics textbooks published by seven publishers). In line with the appeal point of the new national curriculum guidelines, namely proactive, interactive and deep learning, in all the textbooks between two to six main characters consisting of both boys and girls appear, raise ideas about mathematics studies, and proceed with proactive and interactive learning.

The number of boys and girls is basically the same, and stereotyped situations such as boys playing sports and girls cooking have disappeared.

Fig. 3 shows a group of four boys and girls discussing where the location that experiences the most excessively hot days. The main characters going through the learning with readers each have a name, and the proportion of boys and girls is equal. They both express their thoughts and there is no bias in roles of expression.

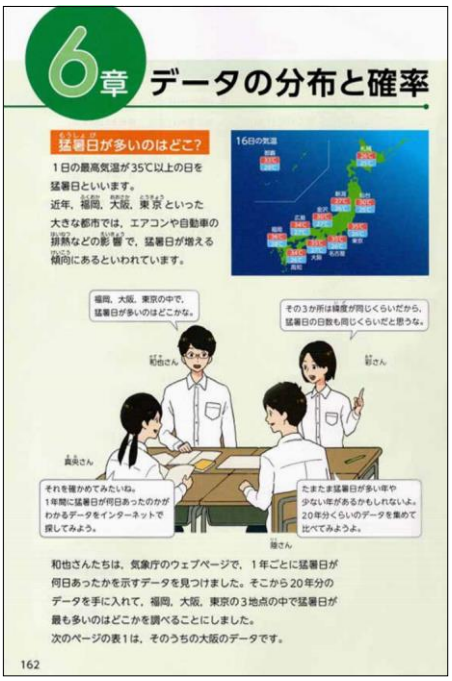

Fig.3 Gender and roles of students appearing in textbook for lower secondary school students published in 2021 (Lower secondary school Mathematics 2, p. 162, Nihon Bunkyou Shuppan Co., Ltd., 2021)

Note: All six of the elementary school textbook publishers and all seven of the lower secondary school textbook publishers depict between two to six main characters consisting of both boys and girls appear, who raise ideas about mathematics studies, and proceed with proactive and interactive learning. The proportion of boys and girls is more or less equal and their words and the roles of their actions are gender-balanced.

Compared to the consideration shown towards the depiction of pupils and students in the textbooks, it appears that less thought has been given to the illustrations of the teachers depicted, particularly in the

case of the lower secondary school textbooks. In some textbooks no teacher appears at all, and the learning is led only by children and students.

(3) **Mini-essays on jobs using mathematics**

One of the co-researchers in this research project, Hisae Kato, conducted and analysis of the characteristics of textual context in the area of functions in lower secondary school textbooks published in the year 2016. Kato thought that mini-essays in textbooks have the potential to diversify students' views regarding mathematics, and if women appeared in them they could serve as role models for girls and be useful in career education. However, only one publisher printed these sort of mini-mini-essays, and even that publisher's mini-essays on functions portrayed adult men in the textbooks for all three lower secondary school grades. (Kato, 2019).

Tab. 1 Characters appearing in "mathematics at work" mini-essays in lower secondary school mathematics textbooks (comparison of textbooks published by Dainippon Tosho Co., Ltd. From 2016 to 2021)

2016				
Study area	Numbers and formulae	Diagrams	Functions	Use of material
Grade 1	Weather forecaster (female)	Carpenter	Mathematician	Baseball business analyst
Grade 2	Japan Aerospace Exploration Agency development staff member (female)	Mathematics theoretician (female)	Shinkansen transport planning group	Actuary
Grade 3	Mathematician (number theory)	Urban development project manager	Software developer	Newspaper journalist

2021				
Study area	Numbers and formulae	Diagrams	Functions	Use of data
Grade 1	Pilot (female)	Artist	Earthquake, tsunami & volcano disaster researchers	Sport data analyst
Grade 2	Nutritionist/school nutritionist (female)	Puzzle creator (female)	Railway operation management	Data scientist
Grade 3	Space physics researcher	Miniature photographer/figurine maker	Pharmaceutical company researcher (female)	Nature protection ranger (female)

Note: In the 2016 school year there were no female-based mini-essays in "Functions" and" Use of material" in lower secondary school third grade textbooks, but female-based mini-essays were incorporated in each study area and each grade in the 2021 school year. It is to be hoped that the choice of jobs using mathematics will widen.

Among the textbooks published in 2020 and 2021, the arithmetic textbooks of two publishers and the mathematics textbooks of four publishers contained mini-essays, both of which represented an increase. A comparison of the lower secondary school mathematics textbooks with mini-essays in 2016 and 2021 showed that, as illustrated in Tab. 1 above, there were improvements in the 2021 school year with mini-essays featuring women in every study area and at each grade.

It is important that mini-essays concretely show the relationship between the content of mathematics studied in each grade and occupations. For example, a section entitled "Discovery! Mathematics at work – pilots," in a mathematics textbook for first grade lower secondary school students showed the name and photograph of the co-pilot of a Boeing 737. It shows how the co-pilot's clock and flight plan use "Zulu time," explains that the local time in the US state of Arizona is minus 7 hours against Zulu time, that when the time difference with Japan is calculated it is mius 16 hours, and that care should be taken when contacting people in foreign countries in order not to inconvenience them. Students thereby discover that the calculation of negative numbers that they learn in the first grade is used in real life, and this can hopefully broaden the images of the use of mathematics in work and occupations pursued by women.

4. Materialization of methods to create an awareness of the unperceived

(1) Outline of the Educational Material for Instructors released in March 2021 by the Gender Equality Bureau, Cabinet Office

There are examples of initiatives taken in other nations by governments, researchers and schools. In Japan too, the first collection of literature by the government and researchers has been published by the Gender Equality Bureau, Cabinet Office. It is to be hoped that this document will serve as the first step in encouraging improvements.

Chapter 1 explains the actual state of girls' drift away from mathematics and the fact that the causes behind this are in the environment; Chapter 2 covers activities portraying mathematicians and the unintentional and unconscious manner in which teachers conduct tuition; Chapter 3 consists of a commentary on the previous chapter and a glossary of terms regarding three activities and gender; Chapter 4 provides two cases studies on mathematics lessons and one on physics lessons; and Chapter 5 contains three essays written by a television station employee, robotics scientist and pharmaceutical company employee.

(2) Outline of mathematics in the Educational Material for Instructors of Gender Equality Bureau, Cabinet Office

Below I offer a brief introduction to the coverage of mathematics in Chapters 2 and 4.

(i) Chapter 2: Understand yourself

- Teachers are asked to draw a picture of a mathematician in a blank space on the page, and questioned about the sort of person they drew.
- The issue of ways of praising girls is raised, with phrases such as "You're great! You can do mathematics and physics even though you're a girl."

(ii) Chapter 3: Look back on your daily conduct

- Commentary on Chapter 2: When activities to depict mathematicians were conducted at schools in the UK and US, the majority of students drew "a white male with glasses and a beard, either balding or with eccentric hair, standing in front of a blackboard with a simple equation such as 1＋1＝2 written on it."
- Due to space limitations I will introduce just one activity. Activity 1: Unconscious bias is thought about through a discussion on what two male and female second grade high school students with identical profiles should study in the third grade, what they will be doing one year after graduation, and what they will be doing at the age of around 30 years of age.

(iii) Chapter 4: Science and mathematics teaching – introduction of case studies

- Case study 1: The cases study incorporates material placing the spotlight on how mathematics is used in daily life, in an effort to raise the interest of girls in mathematics. As girls have a tendency to concentrate on writing neatly in their notebooks, the initiative keeps writing on the classroom blackboard to a minimum and eagerly adopts a cooperative learning method in which a single problem is tackled in groups.
- Case study 3: The aim is that the students can continuously use metacognition (the ability to be objectively aware of themselves), maintain their own awareness of problems, study, reflect and study again in a circle of inquiry. Attention is paid to ensure that the metacognition of "girls can't do mathematics" is not allowed to take growth, and improvements such as meticulously setting questionnaires are repeated.

(3) Utilization of and prospects for the Gender Equality Bureau, Cabinet Office's Educational Material for Instructors

With regard to part of this volume, experiences and impressions were sought from those studying on the teacher training course at two universities (during April and May 2021). The student profiles differ according to the university and department, and they were not questioned from a perspective specifically imaging that they would be teachers in the future, but I will describe the future prospects using them as referential cases.

(i) Regarding "drawing a mathematician" in Chapter 2 and the commentary in Chapter 3

This question is to raise awareness of whether the subject has a preconception of mathematicians as "white males." As no female mathematicians appear in the elementary school or lower secondary school textbooks, preparations should be made so that teachers can respond when they are asked who is a female mathematician? It would be extremely difficult to link in and explain the research of figures like Sofya Kovalevskaya, the first Russian female to become a university professor, with the content of mathematics taught at elementary and lower secondary schools. In the midst of the ongoing COVID-19 pandemic statistics have become a more familiar topic. While she was not a mathematician, the suggestion of Florence Nightingale, who contributed to mathematics not only through mortality statistics but research into nursing days, and has been called "the mother of statistics," (Senuma, 2021) was regarded as convincing by a large number of students. Furthermore, opinions were voiced regarding the commentary in Chapter 3, some suggesting that rather than the gender it was the ethnicity that was the greater problem; some took a positive view of the "simple 1＋1＝2 equation," interpreting it as a representation of the simplicity and stringency that mathematics aims for.

(ii) Regarding the unintentional and unconscious conduct of teachers during lessons covered in Chapter 2

Surprisingly few students had any experience of remarks by teachers such as "You're great! You can do mathematics and physics even though you're a girl," "Girls have a hard time if they pursue the sciences," "Girls are good at writing neatly on the blackboard and taking notes aren't they!" Rather, what had left a more marked impression on them than anything said by teachers were comments from parents or guardians (particularly regarding going on to the next stage of education), friends (regarding notebook appearance) and part-time work employers (that rather than mathematics and science, if you're a girl you ought to be able to cook at least). Opinions that schools may be changing were also observed. It is possible that conduct differs among teachers according to age and gender.

(iii) Activity 1 in Chapter 3: the future of second grade upper secondary school boys and girls

This question asks about the future of a boy and a girl upper secondary school student with an identical profile. The pretext is that they achieve well in English, Mathematics II, Mathematics B, Chemistry, Biology, Physics and World History. When asked what the two upper secondary school students will be doing one year after upper secondary school graduation, many students perceived that there was no gender difference in going on to university. Some thought that rather than academic achievement the emphasis should be placed on whether the upper secondary school students like their subjects and what they want to do in the future. Due to time restrictions, the students were not asked about the question of what the two upper secondary school students will be doing when they reach the age of around 30 years. Since that question is related to how work is viewed and outlooks on life in general, it is predicted that a larger gender difference would be observed than with regard to views about going on

to the next stage of education.

In conclusion

Based on interviews with mathematics education specialists who were pupils or students during World War II the following suggestions have been obtained. That even in the day and age when the educational system for boys and girls differed there were women who studied progressive mathematics; that the mathematics textbooks for girls contained some excellent content; that it is important to also endow men with an interest in the theme of mathematics and gender, and that the fusion of the arts and sciences is essential to the mathematics of the future. (Kunitsugu, 2019, Kagami, Senuma, 2020.) Part of my impetus for pursuing research into mathematics and gender is thanks to Saburo Minato, Professor Emeritus of Akita University, and Motohisa Matsuoka, Professor Emeritus of Yamagata University. I am sincerely grateful to the support of them and many others, and hope to pursue mathematics that are attractive subjects for both genders.

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Supplementary note
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