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Can affirmative action overcome STEM gender inequality in Japan? Expectations and concerns

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ABSTRACT

Compounding skill shortages from Japan's shrinking and ageing workforce is low female participation in research and science-related areas. Why do so few women choose to work in science, technology, engineering and mathematics (STEM)? Previous research suggests the influence of gendered images of STEM fields, but do these apply to Japan, and if so, how? We introduce multiple studies that shed light on gendered images and elucidate the roles of those who affect women's choices and women's own attitudes. Our findings further suggest that a social climate of inequality affects the gendered images of STEM fields. Finally, we offer a critique of recent quota-based systems for increasing women's STEM participation in Japan.

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Affirmative action; gender inequality; Japan; STEM; women in STEM

Introduction

The current Japanese government is calling for the creation of a new form of capitalism in Japan, in part through digital and green transformation (DX and GX). This builds on former government policy to realize Society 5.0, a form of super smart society exploiting the possibilities of artificial intelligence and other new technologies and that is fundamentally human centric in nature. Such a society will require a technologically savvy workforce, yet Japan faces a rapidly ageing and shrinking population. Achieving gender equality and mobilizing female labour in both the economy and research will prove essential, yet Japan faces falling research output and lack of researchers. Further, it faces the risk of contraction, casting a pall over the sector's future (Normile 2022). All this suggests that the human may not be as central to government policy as is claimed, and makes it highly important to understand the position of women in Japan's labour force and in science, technology, engineering and mathematics (STEM) fields in particular.

Japan has the lowest proportion of women at the undergraduate level in STEM among Organisation for Economic Co-operation and Development (OECD) countries. The first half

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of this paper reviews recent Japanese research that focuses on gender perceptions of STEM among multiple groups and the social climate of equality. In Japan, gendered occupational and competence stereotypes are deeply linked to STEM gender images, and they have a similar impact in England, where we conducted surveys of the gendered image of multiple fields. A social climate of inequality, in which gendered differences are socially accepted, also affects the STEM gender image. The second half of the paper discusses affirmative action for gender inequalities through a women's quota in STEM faculties, which some Japanese universities began implementing in 2023. Although there is some criticism, affirmative action has been generally accepted not for social justice but to secure human resources for a modern capitalist society, i.e. Japan. The paper explores potential strategies for Japan to achieve genuine gender equality and remove barriers for women who wish to opt for STEM.

The research environment and social climate in Japan

Japan's scientific research capacity has stagnated in recent years. This is primarily due to the instability of positions for young researchers as a result of university reforms in 2004. At the same time, the percentage of women STEM researchers in Japan is among the lowest in the OECD, and while there has been a slight increase, no significant improvement has occurred.

The proportion of undergraduate women in STEM in Japan is 27% in the natural sciences and 16% in engineering. Fields such as mathematics and physics have fewer than 20%, and mechanical engineering and electrical and electronic engineering have even lower rates. Globally, there are far fewer women than men majoring in mathematics-based fields, such as mathematics, physics, earth sciences, engineering, computer science and economics (Ceci et al. 2014; Kahn and Ginther 2018; OECD 2015).

This century, university enrolment rates for women have increased significantly in developed countries, surpassing those of men in many countries (Goldin, Katz, and Kuziemko 2006; OECD 2015). However, in Japan the proportion of women entering university is lower than that of men, with a 15% lower proportion of women at the undergraduate level, 40% at the master's level and 50% at the doctoral level. Especially at prestigious universities, such as the University of Tokyo, female student enrolment has long hovered around 20%, despite various efforts to increase the proportion. Regional disparities in university enrolment rates are also significant, with higher female participation rates in urban centres and extremely low rates in certain regions. Japan has a strong historical social climate that views women in higher education and the sciences negatively.

The gender gap is further evidenced by Japan's low ranking in the gender gap index published by the World Economic Forum. In 2023, Japan ranked 125th out of 156 countries, with a score of 0.647. (In 2022, Japan ranked 116th out of 156 countries, with a score of 0.650). The gender gap is particularly pronounced in political and economic representation. Given STEM's role in driving the economy, the gender gap is likely to affect the economy in multiple ways.

The Japanese government, led by the Cabinet Office and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), has supported numerous activities aimed at developing female STEM professionals, but these efforts

have not yielded significant change, due to the lack of a clear, evidence-based strategy. Furthermore, the government's top science and technology policy body, the Japan Council for Science, Technology and Innovation (CSTI), has noted a bias towards the humanities in university specializations compared to overseas universities and urges the expansion of science faculties. There are concerns that the population of 18-year-olds is rapidly declining in Japan, a society with a decreasing birth rate, and that the number of science and engineering graduates is also decreasing. In this complex environment the underrepresentation of women in STEM in Japan is a serious issue, and the reasons for this warrant further investigation, which we will now proceed to.

Reasons for the low proportion of women in STEM

Factors reported around the world

The reasons for the under-representation of women in STEM have long been studied worldwide. It is generally believed that STEM requires mathematical competence. In the field of biology, some studies have suggested an innate gender gap in mathematics (Wilder and Powell 1989), but comprehensive reviews have cast doubt on this notion (Ceci, Williams, and Barnett 2009). Many scholars now assert that STEM competence is not attributable to gender but to individual differences.

The (false) perception that female students are less proficient in mathematics than their male peers, commonly referred to as the 'mathematics stereotype', prevails globally. In Japan, an analysis using academic tracking data in one Japanese city (Isa and Chinen 2014) found no differences between boys and girls in primary school, but girls reported lower scores than boys in junior high school. In the TIMSS (Trends in International Mathematics and Science Study) test, Japanese primary and junior high school girls scored slightly better than boys on average, but no statistically meaningful differences have been found since 2003. In the Program for International Student Assessment (PISA), taken by 15-year-olds, Japan consistently ranks highly, and scores between boys and girls show minimal differences, with girls' scores among the highest in the world. Despite their excellent maths skills, however, girls are less likely to pursue science compared to their counterparts in other countries.

In the US, studies have shown that mathematics stereotyping begins as early as 5–6 years old, with girls internalizing this stereotype and therefore underachieving in maths (Spencer, Logel, and Davies 2016; Spencer, Steele, and Quinn 1999). However, mathematics stereotyping can be ameliorated, as Spencer, Steele and Quinn (1999) have shown that reading statements affirming women's ability to achieve the same grades as men improved the performance of female students. In Japan, utterances such as 'even though you are a girl, it's amazing that you can do maths' affect grades (Morinaga, Furukawa, and Fukudome 2017).

Yet career choices cannot be explained by mathematics scores alone (Turner and Bowen 1999). Social factors, including the influence of teachers (Bettinger and Long 2005; Carrell, Page, and West 2010; Lim and Meer 2020) – particularly maths and science teachers (Carrell, Page, and West 2010); friends (Brenoe and Zölitz 2020; Fischer 2017); and single-sex schools (Park, Behrman, and Choi 2018) – have also been noted. The influence

of mothers is particularly strong. In the US, it has been reported that only when mothers rated their daughters' mathematical abilities highly, daughters went on to physics courses at the same rate as sons (Bleeker and Jacobs 2004).

Disciplines and scientists are often associated with particular images. Mathematics, for example, is often perceived as a 'number, objective, abstract, inhuman subject' (Sam and Ernest 2000). In Japan, there are strong gender orientations within professions, with physics often perceived as a male field (Adachi 2014). Furthermore, one educational psychology study found that female Japanese junior high school students may 'pretend' to dislike mathematics and science (Uchida and Mori 2018). Even when they like maths and science, statements such as 'I can do maths' or 'I like science' by adolescent girls could be labelled unusual, and lead to difficulties in forming girls' group friendships because Japanese people dislike being different from others. Changing this cultural environment could make it easier for girls to enter STEM fields.

What is happening in Japan

Gender images such as 'STEM is for men' may be a barrier for women to enter STEM. To understand the situation in Japan, it is necessary to focus on the social climate, including university enrolment rates and the less-than-welcoming atmosphere for highly educated women. In recent years, web surveys have made data collection more accessible. As a result, we collected and analysed relevant data for the Research Institute of Science and Technology for Society (Ristex) project, supported by the Japan Science and Technology Agency (JST) from October 2017 to March 2021. Here we present ten studies, based on a series of surveys, and subsequently offer a comprehensive overview of the challenges involved in increasing the number of women in STEM in Japan.[1]

The first study examines brilliance, an individual characteristic often associated with and seen as a required ability to excel in science subjects. Next, we introduce two studies looking at gendered images of fields or disciplines in society, as some are seen as masculine while others are seen as feminine, which may affect women's choice of field. This is followed by two studies that aim to understand how women's subject choices are affected by their personal views of gender equality. Since decisions are not made in a vacuum, three more studies examine the influences of parents and teachers on female students' choice of field. A further study extends this research to elucidate the social climate surrounding female students' choice of field. The final study provides egalitarian information to participants to see whether motivation towards STEM fields can be influenced.

'Brilliance'

'Brilliance' is a special ability related to intelligence that is exceptional and innate. Among the STEM disciplines, mathematics and physics, in particular, have a strong image of 'Brilliance', or special talent as if bestowed from above. It seems that the stronger the image of 'Brilliance' in a field, the lower the percentage of female PhDs in that field (Leslie et al. 2015). That said, the specific abilities associated with 'Brilliance', and what constitutes their gendered images, remain unclear.

Based on multiple intelligence theory and dual process theory, we organized the abilities required for STEM into seven categories: logical thinking, calculation, memory,

abundant knowledge, ability to judge things quickly, ability to think deeply about things, and ability to grasp the needs of society. We conducted a survey through an Internet research company in Japan and England to determine whether these skills are perceived as male-oriented or female-oriented, and to what extent they are seen as necessary in six STEM fields (Y. Ikkatai, K. Inoue, et al. 2021).[2] Men and women (1177 in Japan and 1082 in England) between the ages of 20 and 69 were surveyed.

The results showed that in both Japan and England, 'ability for logical thinking' and 'mathematical ability' were strongly associated with masculinity, while 'ability to understand the needs of society' was strongly associated with femininity. Physics and mathematics students were strongly associated with excellence in 'mathematical ability' and 'ability for logical thinking', and those in information science and engineering with excellence in 'logical thinking' in both countries.

On the other hand, mechanical engineering students were strongly associated with 'mathematical ability' in Japan, but with 'ability for logical thinking' in England. There were also differences in perceptions of chemistry and biology students. Breaking down the concept of brilliance into component abilities, we showed that while there are commonalities between Japanese and English in whether fields are seen as masculine or feminine, there are also culturally specific associations.

Nursing for girls?

Next, we conducted an Internet survey to examine Japanese gender images in 18 fields, including STEM.[3] A total of 1086 men and women (541 men and 545 women, aged 20–69) were surveyed concerning gender images from the three viewpoints of (a) 'gender appropriateness', (b) 'employability', and (c) 'marriage appropriateness'. We also measured egalitarian attitudes using the Shortened Egalitarian Sex Role Attitude Scale (SESRA-S), which consists of a set of 15 questions developed in the field of psychology to measure egalitarian attitudes.

Nursing was selected by the highest number of respondents as a field suitable for women, and mechanical engineering the lowest. In general, STEM was considered more suited for males than females. Employability was associated with nursing for women and medicine for men. Overall, the results indicate that there is a strong gender image of the fields in Japan, which accords with the actual gender distribution, and that this stereotypical image may be a barrier to girls entering 'male-oriented' fields, especially physics, mathematics, and mechanical engineering (Ikkatai et al. 2020a). People with stronger stereotypical gender images had stronger preferences.

Academic field keywords and gender image

We have seen that different fields of academia have different gender images. What keywords, then, are associated with STEM fields in Japan? Are there gender images for those keywords as well? We extracted representative images for physics, chemistry, mechanical engineering, information science, mathematics, and biology using keywords and examined the gender image of each field and the gender image (masculine or feminine) of the keywords (Ikkatai et al. 2020b).

First, an online survey asked 210 men and women (105 men and 105 women, aged 20–69) to write three words that they associated with each field. 15–20 keywords in each field were then extracted by four independent raters. Names of physicists such as

'Galileo' and 'Einstein' were extracted for physics, and 'covered in oil' and 'welding' for mechanical engineering. Next, we asked 791 men and women (397 men and 394 women, aged 20–69) to rate the gender level for each field and for the keywords extracted on a 5-point scale, and also measured the egalitarian attitude of the respondents using the SESRA-S.

Of the six fields, the one with the most masculine image was mechanical engineering, and the one with the least masculine image was biology, although it still had a masculine image. There was a statistically significant difference between the gender degree of physics, chemistry and biology, and the egalitarian gender role attitudes of the respondents. These results indicate that those with low egalitarian attitudes had a more masculine image of these fields than those with high egalitarian attitudes. As well, women had a more masculine image of these fields than men.

Regarding keywords, respondents with more masculine attitudes towards 'welding', 'making machines', 'tools', and 'machine design' had more masculine attitudes towards mechanical engineering, and those with masculine attitudes towards 'Einstein', 'electromagnetic field', 'relativity', 'thermodynamics', 'principle' and 'theory' in physics had more masculine attitudes towards physics. In other words, masculine images of various fields of science are strong in Japan, and individual (less) egalitarian attitudes may be related to the formation of these masculine images. But there are also strong images that transcend national stereotypes, as noted above.

Women in general science majors dislike physics in junior high school

In Japan, pupils must select physics in university entrance examinations in order to enter engineering and physics departments. However, very few girls choose physics in high school. Therefore, we investigated factors related to selection of physics in university entrance examinations through an Internet survey of 1101 male and female science university graduates (554 males and 547 females aged 20–69).

Both male and female university graduates who chose physics for their university entrance examinations reported that they liked physics in junior high school or in the first year of high school. Women with a college degree in science who liked biology in junior high school or in the first year of high school tended not to choose physics when they took the university entrance examination.

We also examined what kind of activities college-graduate science males and females who reported liking physics in junior high school liked as children. Males with a college degree in science liked 'to play outdoors' in elementary school, while their female counterparts liked, for example, 'reading novels and history books', 'solving difficult maths problems', and 'visiting museums, science museums, and planetariums' in elementary school, and thought that learning physics and arithmetic would be useful in the future in junior high school.

For physicists, the same survey was conducted through the Physical Society of Japan, and responses were obtained from 495 researchers (423 males, 71 females, and 1 other) affiliated with the society. Significantly, while physicists of both sexes were more likely to report that they liked physics in elementary, junior high, and high school, fewer female college graduates of other sciences liked physics in junior high school. As well, physicists tended to have more sex-role egalitarian attitudes than college graduates of other sciences; female physicists particularly had a weaker maths stereotype than other science

graduates. This suggests that reducing the number of women who dislike physics in middle school and having a variety of experiences at an early age may lead to future physics choices for both men and women (Ikkatai, Inoue, et al. 2021B).

Girls with traditional views do not go into STEM

The gender difference in the choice of subject major is thought to be largely due to environmental factors, including parents. Does the environment of Japanese female high school students affect their career choices?

Using data from the 2012 Survey of High School Students and Their Mothers, we compared female students who affirmed the fixed gender role stereotype (e.g. 'men should work outside the home and women should stay at home') with those who neither affirmed nor denied it. The latter were more likely to choose STEM, but we did not find a statistically meaningful relationship between the stereotype of 'males are more capable of using mathematics and specialised skills' and the desire to pursue a STEM career for either males and females, which was surprising, and requires further study. We also confirmed that family environment, such as parental educational background, and household income, had a statistically meaningful relationship with the desire to pursue a career in STEM (Inoue et al. 2021).

Daughters of mothers without stereotypes go into STEM

Using the same data, we examined the relationship between parental gender stereotypes in mathematics and daughters' subject majors. We found that daughters of mothers who disagreed with the statement 'women are less mathematically competent than men' went into STEM fields more than daughters of mothers who agreed with it. The probability of majoring in natural sciences (science, engineering, agriculture, and health) was higher for the daughters of mothers who answered, 'I disagree completely' and 'I disagree somewhat' than for the daughters of mothers who answered, 'I agree completely' and 'I agree somewhat'. On the other hand, this trend was not observed in the relationship between fathers and daughters. This suggests that mothers' gender stereotypes of mathematics may be transmitted to their daughters and may be related to their daughters' choice of field of study (Inoue 2019).

Non egalitarian parents oppose higher education in general

In another internet survey we focused on the possibility that parents' gender equality and gender role attitudes influence girls' career choices, measuring the gender equality and gender role attitudes of 1236 parents (618 mothers and 618 fathers) of daughters and sons (of any age) with college degrees or higher, through the SESRA-S. Parents with higher SESRA-S scores (more gender-equal and less gender-role-oriented) were more positive about female students' university study, while parents with lower scores (more gender-unequal and more gender-role-oriented) were more negative about female students' university study, in *any* field.

More than 40% of all parents surveyed were in favour of female students going on to higher education if they wished to do so, 'Because they won't have trouble finding a job' in science fields and 'Because it is suitable for women' in humanities fields. The field in which parents were most in favour of science education for female students was pharmacy. Reasons given by parents opposed to female students entering the sciences

included 'It is not suitable for women' for engineering in general, 'Because it is hard work' for veterinary medicine, animal science, and nursing, and 'Because the tuition fees are high' for pharmacy, medicine, dentistry, and information science, biology, mathematics, and physics. Parents in favour of these fields chose 'Because they won't have trouble finding a job' (Ikkatai et al. 2019).

Teachers only recommend physics over biology to male students

The percentage of girls who choose physics as a science subject in high school is very low in Japan. We focused on the influence of high school teachers as one external factor. An online experiment was conducted with 316 high school teachers (257 males and 59 females) through an internet research company. Teachers were asked to read seven scenarios describing situations in which a high school teacher advises high school students who are struggling to choose between physics and biology, and to indicate to what extent they agree with the advice of the high school teachers in the scenarios. For each scenario, the high school students were given a female name, a male name, and an alphabetical name.

The relationship between the degree of agreement with the high school teacher's advice and the gender of the high school students was examined. We found that the participants recommended physics more strongly than biology when the student had a male name, under certain circumstances. In Scenario F, for example, 'I think physics offers more department options' was often selected as the reason for agreeing with the teacher's advice, and applied to male students. Overall, the results indicate that there may still be a gender bias that strongly associates boys with a wide range of future options (Minamizaki et al. under review).

Social climate in Japan and England

Cheryan et al. (2017) proposed a model to explain the low number of women studying computer science, engineering and physics in the United States using three groups of questions (masculine culture of the fields, insufficient early experience, and gender gaps in self-efficacy). We considered it necessary to add a fourth group – social climate of inequality, to explain the masculine image of mathematics and physics in Japan.

Responses from 1177 men and women (594 men and 583 women, 20–69) living in Japan and 1082 men and women (529 men and 553 women, aged 20 to 69) in England were compared. In Japan both mathematics and physics had statistically significant effects on 'employment', 'maths stereotype' and 'image of being smart'. In other words, people who viewed mathematics or physics as masculine were also more likely to think that the occupation in which they would find a job after studying mathematics or physics was male-oriented, that women had less mathematical ability than men, and that people who entered a mathematics or physics departments were generally smart. The effect of 'views of intelligent women' was statistically significant only for mathematics; i.e. those who disagreed with the statement that 'women should be intelligent' tended to view mathematics as more masculine.

Similarly, in England there were statistically significant effects on 'employment' and 'math stereotypes', for both maths and physics, and a statistically significant effect of 'female role models' in physics. Those who had been told or heard that they would not be popular with the opposite sex if they entered a certain department

tended to regard mathematics as masculine. These results suggest commonalities between Japan and England regarding what influences the formation of masculine images of objects (Ikkatai et al. 2021b). Despite the similarities in gendered attitudes towards STEM fields, however, the fact remains that women's participation in STEM fields is higher in England than Japan. It may be that attitudes towards intelligent women may be a factor. This factor was only significant in Japan and suggests a cultural context in which intelligent women are not appreciated, in contrast to England.

Equality views related to STEM motivation

Finally, we examined whether providing egalitarian information, such as the fact that STEM offers better employment opportunities for both men and women, that a movement is taking place towards a gender equal society, and that no gender difference exists in mathematical ability, would change children's willingness to go STEM schools and parents' willingness to support STEM schools.

An online experiment was conducted with 1,089 first-grade junior high school children (544 boys and 545 girls) and their parents (534 men and 555 women) through an internet research company. The children and parents were asked to read specific information, and to answer the same questions before and after reading the information. The information was categorized into four types – (a) employment in STEM, (b) egalitarian society, (c) absence of a gender difference in maths ability, and (d) irrelevant information – and provided to the participants in one of four combinations: (a) only, (a) and (b), (a) and (c), and (d) only. We anticipated that information on (a) STEM employment would have been provided at the many events held to support women's entry into STEM, so this was used as the basis for providing information in (b) and (c) in combination.

We found that the children who received information about both (a) and (b), and those who received information about both (a) and (c), were more likely to be motivated to enter STEM fields. Parents who were given information on both (a) and (c) also showed an increase in their willingness to support their children's STEM education. The results indicate that the provision of information, especially egalitarian information in conjunction with employment information, may be effective in motivating children and their parents to pursue STEM education in the short term (Ikkatai et al. 2021a).

The future of STEM gender in Japan

The above ten studies revealed that gender image in academic fields is associated with the level of equality. However, as revealed in the final study, this could be rectified to some extent by providing factual information that contradicts existing perceptions.

On the other hand, some results were unexpected. For example, the results in the fifth study above showed that female students do not go on to study science due to gender stereotypes, that is, gender role consciousness matters rather than mathematics stereotypes. The results in the ninth study also showed that attitudes towards intelligent women in Japan may be a barrier to women's participation in STEM. These results suggest that

resolving women's low STEM participation rate may require changes to Japanese social attitudes rather than simple interventions.

Accelerated gender affirmative action in STEM, 2023

In 2023, a decision was taken in Japan to establish a 'women's quota', a recommendation system exclusively for female students, in several Japanese university engineering departments, with leadership taken by the presidents of the respective universities. The universities were Nagoya University, the University of Toyama, Shimane University, the Tokyo Institute of Technology (to be merged with Tokyo Medical and Dental University) and the Tokyo University of Science, while Shibaura Institute of Technology has done so since 2018. Tokyo Institute of Technology is particularly popular as a high-level university in Tokyo, and attracts considerable attention due to the scale of its quota for women: in 2024, for a total of 143 students, or 14% of the bachelor's degree programmes each year.[4]

Different requirements are set for women under these recommended quotas, and they differ from the general admission requirements for which women can also apply. For engineering entrance examinations, applicants must normally study high-level mathematics, known as Mathematics 3, in their third year of high school, and they are often required to choose physics from among the science subjects. Under the quota for women, however, female applicants can receive a recommendation even if they have not studied these subjects. Moreover, Ochanomizu University and Nara Women's University have announced the establishment of engineering faculties. These women's universities have long histories, and admission is restricted to female students from the outset. (Since 2020, Ochanomizu University has allowed transgender students whose gender identity is female to enrol.) While the public mood is generally in favour of the establishment of engineering departments in women's universities, some argue that affirmative action is a form of reverse discrimination. The next sub-section discusses issues of affirmative action aimed at increasing the proportion of women in STEM fields in Japan.

Background to Japanese-style gender affirmative action

Affirmative action, especially a women's quota in university admissions, has not been common in Japan until now, and sufficient social discussion has also been lacking. The Japanese entrance examination system is generally a score-based system. Students are accepted or rejected by private universities mainly on the basis of their scores in their respective university examinations, and by national universities on the basis of their scores in the common examinations and the examinations of the respective universities. Going to a 'good' university is considered a shortcut to a stable job, and competition in university entrance examinations and secondary school entrance examinations that lead to them is fierce. To some extent, universities accept a diverse range of people, such as those with comprehensive selection examinations based on essays and interviews. The University of Tokyo, for example, has had an entrance examination quota for school recommendations since 2016. These students, however, are accepted based on excellence in some area of activity. Overall, however, the entrance examination system in Japan is based on scores.

Against this backdrop, Kyushu University's announcement that it would provide a women's quota in the Department of Mathematics in the Faculty of Science from 2012, but this was subsequently withdrawn due to public criticism that it was reverse discrimination. It was also argued that a women's quota is problematic because it 'stigmatises' women who are accepted because they are female (Tsujimura 2011). Ten years later in 2023, when many universities, including the Tokyo Institute of Technology, simultaneously proposed quotas for women in engineering departments, similar criticism arose, but not as intensely. These quotas appear to be based purely on students' interest in the field and feature lower hurdles to entry.

Japan's gender gap index (GGI) score has not changed significantly since it was first published in 2006, but its global ranking has declined; from 80th in 2006, to 125th out of 146 countries in 2023, which is the lowest among developed countries. These annual rankings have been widely reported over the past few years, which is stimulating discussion in society.

Universities are also expected to make the necessary reforms, and the University of Tokyo, for example, made headlines by making five of its nine presidents and board members (i.e. the majority) women by 2021. It has further set a target to hire 300 female professors and associate professors by 2027 fiscal year and to increase the percentage of female faculty members from 16% to 25%. However, to achieve this goal, the number of women entering Ph.D programmes and obtaining Ph.Ds needs to increase.

The representation of women in senior positions is also a major challenge in industry. In April 2013, the government made the modest request that one board member in each company should be a woman, but in 2023, the percentage of female board members was still low at 15.5% versus the OECD average of 29.6%, and the government is calling for a further increase. In particular, STEM companies have expressed a strong desire for female STEM personnel. While some companies are promoting activities to support women's recruitment and there are some changes appearing, such as Japan Airlines' recent appointment of a former cabin attendant as the company's first female president and the Nissan Foundation's award for activities that promote women's choice of STEM, there remains little change overall, despite this need.

The Japanese government has made efforts to promote female STEM personnel. These were initially aimed at increasing the number of female students, as the number of STEM personnel is decreasing due to the super-ageing society and declining birth rate. Gradually, however, the concept of diversity has been updated. One representative activity is *Rikochare*, or STEM challenge, which takes the form of role model introduction events organized by the Cabinet Office in collaboration with industry. This long-running activity introduces women working in STEM companies to junior and senior high school students. The Cabinet Office also funds these activities for universities. However, the proportion of women in engineering has only increased slightly. In other words, for a long time efforts to increase the number of female students, both at the initiative of the government and various universities, have failed to produce significant change.

Given these circumstances, the proposed quotas for women in STEM by the respective universities have not been met with much opposition from society, although they have been criticized on social network service (SNS, e.g. X) as a form of reverse discrimination against men. Some were also angered by the inference that universities considered women to have inferior abilities.

Positive and negative aspects of the women's quotas: is that social justice?

The positive message to female students with the establishment of quotas for women in engineering may be significant. More than ever, it shows that universities and society are serious about wanting women in STEM. This may help female students to consider pursuing a science major, and encourage parents and teachers to support this. On the other hand, there are concerns. First, there is concern that the message conveyed is that universities believe female students are not as capable in mathematics and physics as their male counterparts, and that interest alone is sufficient for entry to the field. The academic achievements of Japanese female students in science-related fields are top-notch, and many exceptionally talented female students tend to aspire to enter medical schools. The important thing is to increase girls' interest in STEM and help them find jobs, reduce their dislike of maths and physics, and encourage them by repeatedly sending the message that they are capable.

Second, the question of whether women can keep up with regular lectures has arisen. The quota is a recommendation, and there may be some difference in academic ability between these women and students who pass the regular entrance examinations. Third, these students may be subjected to the stigma that they were only admitted because they are female, and this may also affect female students admitted under the regular entrance system, who will receive the same lectures in mixed classroom situations. Other students will not know which entrance examination they have passed unless they declare this themselves. Fourth, even if a university offers places for women, the programme may fail to attract sufficient applications from female students. Kanazawa Institute of Technology, which introduced a quota for women in 2008, only had 12 applicants out of a capacity of 40, and in 2009 the programme was cancelled after it received only 13 applicants.

Generally, affirmative action is carried out as a social justice measure to correct inequalities. Japan's establishment of quotas for women was driven by a labour shortage as a result of an ageing society and a social drive to promote gender equality, which calls for universities to develop female human resources in the sciences. However, even with this background in mind, can Japan's affirmative action be called social justice? Rather, imposing quotas for female students suggests that women's abilities as being unreasonably undervalued, and this appears to be the result of a strong gender bias regarding abilities. Another factor may be that there are not enough women in the executive departments of universities that have promoted affirmative action. Our research revealed that, the masculine culture of STEM and a social climate of gender inequality in Japan strengthen the image of STEM as masculine. Universities' executive branches should be the first to understand this situation. Increasing the number of female students will lead to a higher evaluation of the university, and the quota for women may be an easy goal to achieve. But we are concerned that there has not been sufficient discussion of the matter.

Assuming that affirmative action in the form of quotas for women in STEM continues for some time in Japan, flexible university management is needed to deal with possible problems. In particular, it is important that universities fulfil their responsibility for: a) supporting the studies of students admitted under the female quota. Follow-up surveys should be conducted to confirm whether there are any changes in graduation rates, etc; b) paying attention to whether female students suffer from stigma; and c) fostering social discussion, and the content of the discussion should be made open.

The quotas for women in engineering face many challenges. They appear to be supported in the current atmosphere in 2023, but they may not last into the future. Careful and continuous explanations and commitment from universities are important. Rather than implementing women's student intake quotas, universities need to change the university and social climate by eliminating mathematics stereotypes in society. And they need to explain the employment advantages and the benefits of increasing gender equality so that women can choose career paths they want to study without women's quota. Finally, while some women who choose STEM fields go on to become researchers, an essential human resource needed by Japan, as we have seen, implementing undergraduate quotas may negatively impact the position of women in STEM fields by undermining trust in women's ability.

Discussion: extending diversity in STEM in Japan

This paper has reviewed gender image and equality issues in STEM in Japan. It has also discussed recent affirmative action 'women's quota' initiatives. It is important to disseminate information that introduces children to professions they are interested in, and to promote gender equality and reject stereotypes about mathematics. While broadcasting and newspapers have recently disseminated valuable information, further enhancement on platforms such as YouTube and SNS which are popular among children is needed. It is vital for various stakeholders to create a multi-layered information environment with a focus on gender equality.

What distinguishes Japan from other developed countries is its accelerated ageing and need for change at a time when the use of ChatGPT and AI is being promoted and job insecurity is increasing. Occupations such as bank tellers, traditionally dominated by women, are expected to disappear *en masse*, and more students are expected to choose science-related professions. Programming education became compulsory in elementary schools in Japan in 2020. Programming and simple tasks will be carried out by ChatGPT, which will require highly skilled personnel who can use AI and provide instructions.

In our parent survey, the field in which parents were most supportive of women pursuing higher education was computer science. Historically, the representation of women in computer science has been exceedingly low, but a breakthrough may arise in Japan where job demands, educational opportunities and parental support are aligned. Children with programming education will enter university in 2032. We hope a full-fledged era of STEM gender equality and a society that believes in and supports the talents of female students will follow. The main reason for the recent scarcity of STEM women in Japan is seen to be the substantial gender disparity in academic backgrounds (Yamaguchi 2023). We hope that the increase in STEM women will contribute to closing the gender gap and create the human resources to maintain Japan's research output into the future.

Notes

1. The following survey overviews were originally published in Japanese as a report for the JST-Ristex project and are here translated into English by the authors with additional information.

2. The STEM fields were physics, mathematics, biology, information science and engineering, mechanical engineering, and chemistry. The reason for limiting it to England rather than to the entire UK is that the education system in England is unified.
3. The fields were mathematics, chemistry, physics, mechanical engineering, information science, biology, agriculture, geology, medicine, dentistry, pharmacy, nursing, law, economics, social sciences, humanities, music, and fine arts.
4. https://www.titech.ac.jp/english/news/2022/065243 accessed 9 February 2024.

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