Consultant Report

Securing Australia's Future

STEM: Country Comparisons

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STEM Country Comparisons: Japan

Mayumi Ishikawa , Shota Fujii
Ashlyn Moehle, Osaka University

Table of contents

List of Tables and Figures

0. Executive Summary

Although awareness of the critical importance of STEM education and training pervades Japanese mainstream academic and industrial leadership (and has for several decades), acute crises such as the Fukushima Nuclear Plant disaster in March 2011 as well as an auspicious occasion of a Japanese scholar being awarded a Nobel Prize thrust this awareness to the surface of public consciousness. Such episodes, both positive and negative, manifest contradictory trends that surround STEM in contemporary Japan.

There is no explicit, national STEM policy in Japan. Rather, the strategies, policies and programs that affect various aspects of STEM and STEM education are implicitly present in more comprehensive measures that concern broader aspects of education and the training of human resources. In the compilation of this report, the Japanese terms '*rikakei*', '*rikei*' and '*rikō kei*' are used as translational equivalents of STEM. These terms include life and health sciences as well as computing and information sciences, unless otherwise specified.

Through its remarkable technological development following World War II, robust scientific output generated by research activities at world-class universities and institutions and distinguished achievements in basic science, Japan has been conferred the status of 'a nation of scientific and commercial innovation'. Nevertheless, these indicators of high standards and progress emerge against the backdrop of an alarming decline in both STEM popularity and performance, further compounded by major challenges facing a nation in transition toward a post industrial society or knowledge-based economy.

Section 2 provides a brief overview of the role of science and technology in Japan's modern and historical context and discusses key legislation, such as the Basic Science and Technology Law of 1995, which ushered in a series of reforms with significant, wide-reaching effects, including provisions for reexamination and revision of mid- to long-term science and technology policy.

Section 3 presents a detailed analysis of data gathered on Japanese students' STEM performance as indicated by international comparisons such as PISA and TIMSS, attitudes toward STEM, participation in STEM at the primary, secondary and tertiary levels, career paths for STEM graduates, and the representation of women in STEM education, research and careers. This analysis yields a picture of STEM in Japan that features the following critical issues: 1) Lack of enthusiasm for science and technology both among children and Japanese society as a whole; 2) Declining enrolment in STEM classes and courses at the senior secondary and undergraduate level; 3) Lack of teachers with in-depth knowledge of STEM subjects; 4)

Lack of clearly established career paths for postdoctoral STEM researchers despite the expansion of graduate programs; 5) Low enrolment of female students in STEM courses and gender disparity in STEM careers.

Section 4 examines the strategies, policies and programs created and implemented by MEXT (the Japanese Ministry of Education, Sports, Science and Technology) along with other agencies to address the critical issues identified in Section 3. Four key strategies in particular are considered: The first is the enhancement of compulsory STEM education through a major revision to the national Curriculum Guidelines that resolves to increase the study hours and content of math and science classes in primary and secondary schools, as well as other programs aimed at transforming approaches to teaching and learning. The goal of these initiatives is to improve the quality of basic STEM education nationwide, generating and stimulating interest in scientific topics and thus creating a broad support base for STEM in Japanese society. The second involves programs to nurture and train the best and brightest STEM talent by enhancing 'elite' education. This is exemplified by the Super Science High School (SSH) program launched in 2002 along with subsequently established programs that lay the foundation for a 'science elite track' from secondary to tertiary levels of education. The third facilitates university to career transitions by supporting job placement of graduate students and post-doctoral researchers who complete degrees in STEM fields. The fourth specifically addresses the underrepresentation of women in STEM education and careers and features initiatives supported through both public and corporate sector funding.

Section 5 provides a preliminary assessment of the policies outlined in Section 4 and raises the question of whether synthesizing the two strands of policy (broad-based education and elite track) might deliver a more effective solution to the documented apathy toward science regarded as the most difficult challenge for Japanese national STEM promotion and enhancement. Citing experts' evaluation of past policies, it is suggested that the creation of targeted programs and an analysis exclusively focused on narrower STEM fields may also be warranted. In contrast, the robustness of Japan's public education system, recent qualitative improvements in teaching methods and constant revision of curricula are presented as strengths that must be utilized in long term planning while guaranteeing autonomy for educational institutions.

1. Introduction

1.1 Nobel Prize and Fukushima: Pride and lost faith in Japan's science and technology

News of Kyoto University professor and life science researcher Shinya Yamanaka's having been awarded the 2012 Nobel Prize in Physiology or Medicine for his research on adult stem cells was widely reported in the Japanese media and celebrated across the nation. Building on a track record of having produced ten Japanese Laureates who received the Prize since 2000 in scientific fields such as Chemistry and Physics, Japan gained international recognition for Yamanaka's work that testified to the country's high level of scientific research. In addition, it showcased a successful example of the nation's recent policies to promote research and development in highly selective key areas.

Yamanaka's achievement also delivered a breath of fresh air to scientific communities in Japan that had endured negative publicity following the Great East Japan Earthquake and subsequent failures at the Fukushima Nuclear Plants in March 2011. Facing a disaster of unprecedented magnitude, scientists who had boasted unparalleled expertise in creating the world's most heavily concentrated network of nuclear power plants in an earthquake-prone archipelago suddenly appeared evasive and untrustworthy. The public's anger over Fukushima was directed not only at the Japanese government and power industry but also at the nation's most prestigious institutions of higher education and research, some of whose members were accused of having proliferated the myth of unconditional nuclear safety and pushing through a pro-industry agenda that greatly shaped the nation's energy policy. Thus, the earthquake and tsunami left deep scars not only in the country's topography but also in the nation's faith in science and technology. Ultimately, the belief that science and technological advancement promise a better future for mankind had been severely tarnished.

In a press conference for the national media following the Nobel Prize Award Ceremony in Stockholm in December, Shinya Yamanaka intimated his strong wish that his success would inspire Japanese children to become scientists in the future. According to Yamanaka, unlike the United States, where many children consider becoming a scientist their dream career and profess their fondness for math and science subjects, far fewer Japanese children claim to either like studying science or consider becoming a scientist an attractive future profession. In fact, several international comparative surveys in recent years have confirmed Yamanaka's worries.

STEM and STEM education in Japan today need to be understood in the context of these contradictory trends. On the one hand, Japan has come to enjoy a high level of research and innovation in science and technology since World War II, exemplified by numerous Japanese recipients of international academic awards and a competitive economy backed by technological prowess. The country's youths generally score high in math and science subjects on various international examinations, though some argue that the outcomes are still not satisfactory. With the standardized national curricula, rigorous teacher training and retraining, routine reviews of subject content, study hours and mechanisms for implementation, the quality of public education is generally regarded as quite high. On the other hand, the country has seen a steady decline in STEM popularity, aspiration and enrolment over the same post-war decades, and the number of students who study or major in STEM subjects at the senior secondary and university level has also decreased. Furthermore, the national job market suffers a grave mismatch between employers and graduates with higher postgraduate degrees in STEM fields.

Such developments, at times contradictory, emerge against the background of wider, structural transitions to a post-industrial society or knowledge-based economy. As the youth population continues to shrink in one of the world's most rapidly aging societies, Japan is also in need of structural reforms that allow participation from broader social strata while ensuring equity of opportunities for women and international workers, to give one example.

1.2. Outline of the report

This report delineates the current status of STEM and STEM education in Japan by highlighting major issues of concern for policymakers and society, analyzing policies, strategies and programs, and offering a preliminary assessment concerning their impact and effectiveness. The following section (Section 2) provides a brief overview of key legislation regarding major policy issues in order to facilitate a contextualized understanding of STEM in Japan.

Building on the above, STEM provisions, attitudes toward STEM, participation in STEM in schools and career paths for STEM students are examined in Section 3 along with statistical data and evidence from other sources, including international comparisons of STEM education such as PISA and TIMSS. The main purpose of this section is to analyze the present situation and identify the critical issues pertaining to Japanese STEM education. These provide the basis for the four major strategies presented in Section 4 that enhance STEM in four key areas of education: 1) science advocacy programs to generate interest and enthusiasm among the general population, especially among young children; 2) 'elite' science programs to nurture and encourage the brightest talent from high school (upper secondary) to post graduate levels; 3) programs to ensure successful career linkage from university to labor markets; and 4) programs to rectify the underrepresentation of women in STEM subjects, research as well as workplaces. The final section (Section 5) of the report presents a preliminary assessment of STEM strategies and programs up to late 2012.

1.3. Definition of STEM

There is no equivalent term for STEM or 'science, technology, engineering and mathematics' in Japanese. This report thus relies on existing data in Japanese that concern '*rika kei*' or '*rikei*' for short. These are commonly used terms that broadly denote 'science disciplines' or 'science fields', in contrast to studies in the arts, humanities and social sciences. For senior secondary and tertiary levels of education and beyond, STEM roughly corresponds to the alternative terms '*rikō kei*' or '*risū kei*', which translate to 'science and engineering disciplines' or 'science and mathematics disciplines'. These terms specify the inclusion of 'engineering and relevant technical fields' and 'mathematics' along with science disciplines in general. For STEM at the primary education level, we use data related to two subjects, '*rika*' and '*sansū*', or 'science' and 'mathematics', respectively.

The terms '*rikakei*', '*rikei*' and '*rikō kei*' are thus used as equivalents of STEM throughout this report unless otherwise specified. These terms include life and health sciences as well as computing and information sciences, also unless otherwise specified.

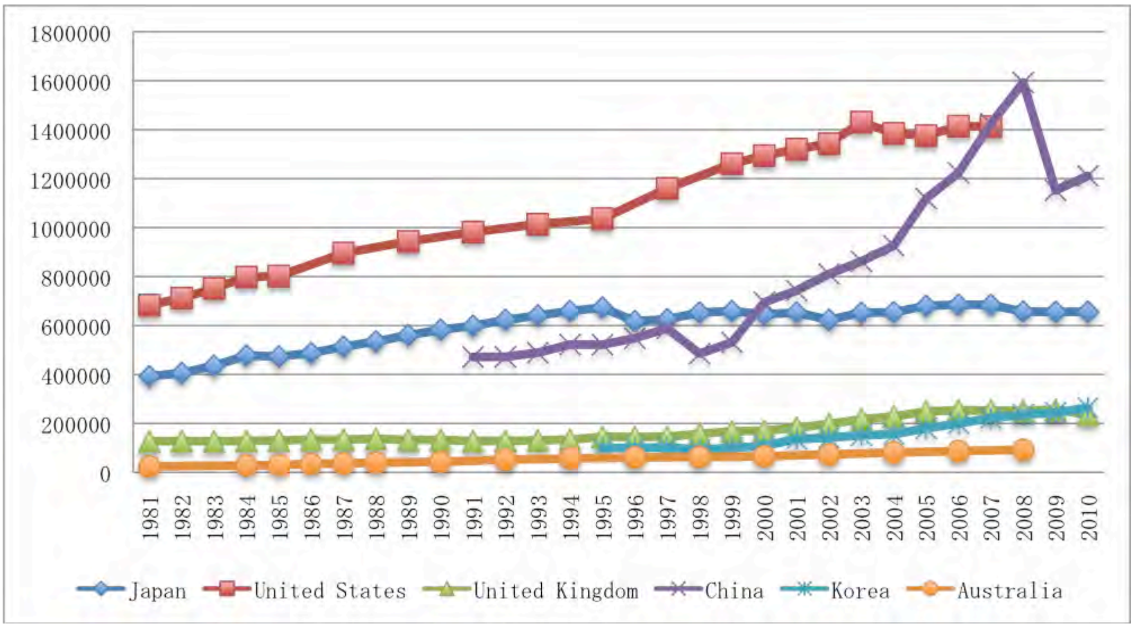
2. Status of science and technology in Japan and policy background

2.1. International competitiveness of Japan's science and technology

By presenting a series of examples showcasing successful developments of science and technology in post-Bubble Japan, Holroyd and Coates (2007:8-9) argue, 'Japan has reasserted itself as a nation of scientific and commercial innovation'. Amid persisting economic woes and the global challenges of industrial restructuring, Japan has not only achieved considerable success in targeted areas of science and technology, but has also managed substantial scientific output through research activities carried out at its universities and research institutes, in addition to distinguished achievements in basic science.

Japan features a broad base for science and technology research in terms of total and per capita research personnel numbers. According to the OECD database (OECD 2012a), Japan maintains more than 650,000 researchers, the third largest number in the world after the United States and China (see Figure 2.1.1).

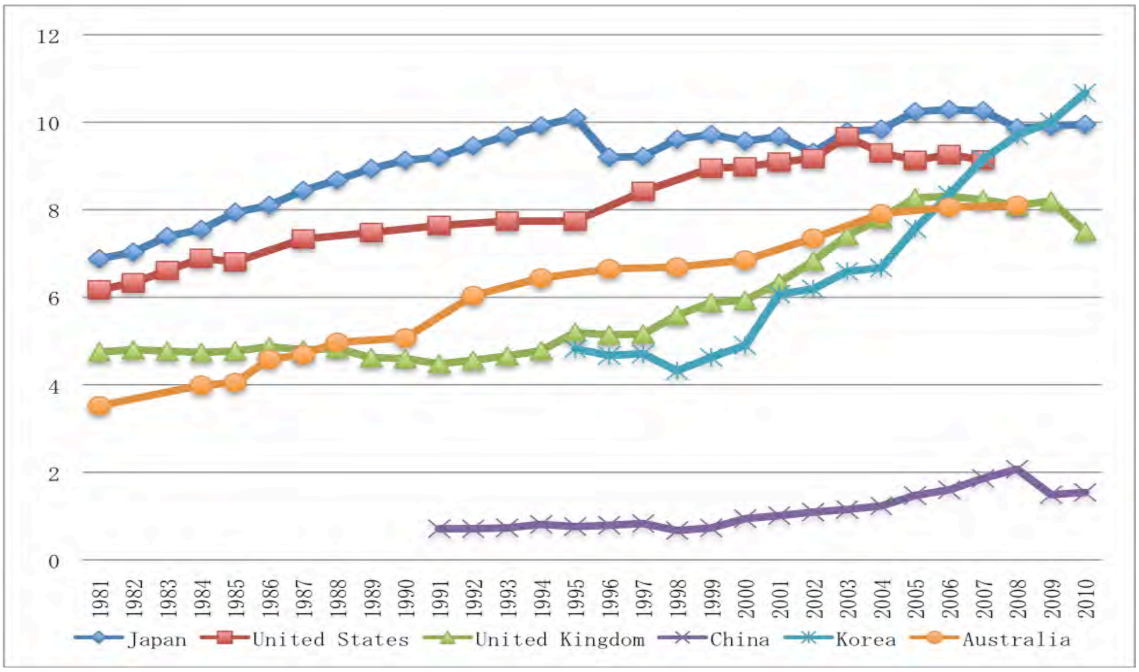
Figure 2.1.1. Number of researchers



from OECD Main Science and Technology Inidicators (MSTI), http://www.oecd.org/sti/msti.htm

In 2010, Japan produced 9.95 researchers per one thousand labor force workers, one of the highest ratios in the world (see Figure 2.1.2).

Figure 2.1.2. Number of researchers per thousand labor force workers



from OECD Main Science and Technology Indicators (MSTI), http://www.oecd.org/sti/msti.htm

Although per capita researchers have increased drastically in Korea, Australia and the United Kingdom over the past three decades, the actual number of researchers in these countries remains fewer than 250,000. Consequently, Japan still produces many more scientists and engineers than most nations, 'thus providing a steady flow into the laboratories and development facilities in the nation's research centres and factories' (Holroyd and Coates 2007:166). This picture may change, however, in the near future due to declining fertility rates and rapid aging of the population. According to a survey commissioned by MEXT, on top of the maximally projected increase in researchers, an additional 0.16 million researchers and 1.09 million engineers will be required by 2030 in order to preserve an annual economic growth rate of 2 percent (MEXT 2006:91-104). This constellation of factors constitutes one of the most urgent and precarious conditions for Japan's science and technology future and will be revisited later in this report.

As another indicator of national innovative strength, Japan accounts for 21.4% of the world's 181,900 patent applications, second only after the United States, according to the World Intellectual Property Organization (WIPO) database.[1] Notably, Japanese patent applications have increased some 40% since 2007 (see Table 2.1.1).

Table 2.1.1. WIPO-PCT application ranking by country

Rank	Country	2011	2010	2009	2008	2007	Proportion 2011	Percent increase (2011/2007)
1	USA	48,596	45,008	45,627	51,642	54,042	26.70%	-10.08%
2	Japan	38,888	32,150	29,802	28,760	27,743	21.40%	40.17%
3	Germany	18,568	17,568	16,797	18,855	17,821	10.20%	4.19%
4	China	16,406	12,296	7,900	6,120	5,455	9.00%	300.75%
5	Korea	10,447	9,669	8,035	7,899	7,064	5.70%	47.89%
6	France	7,664	7,245	7,237	7,072	6,560	4.20%	16.83%
7	United Kingdom	4,844	4,891	5,044	5,467	5,542	2.70%	-12.60%
8	Switzerland	3,999	3,728	3,672	3,799	3,833	2.20%	4.33%
9	Netherlands	3,494	4,063	4,462	4,363	4,433	1.90%	-21.19%
10	Sweden	3,466	3,314	3,568	4,136	3,655	1.90%	-5.17%
11	Canada	2,923	2,698	2,527	2,976	2,879	1.60%	1.52%
12	Italy	2,671	2,658	2,652	2,883	2,946	1.50%	-9.35%
13	Finland	2,080	2,138	2,123	2,214	2,009	1.10%	3.53%
14	Australia	1,740	1,772	1,740	1,938	2,052	1.00%	-15.21%
15	Spain	1,725	1,772	1,564	1,390	1,297	0.90%	33.00%
	Others	14,389	13,346	12,656	13,726	12,595	7.90%	11.24%
	Total	181'900	164'316	155'406	163'240	159'926	-	13.74%

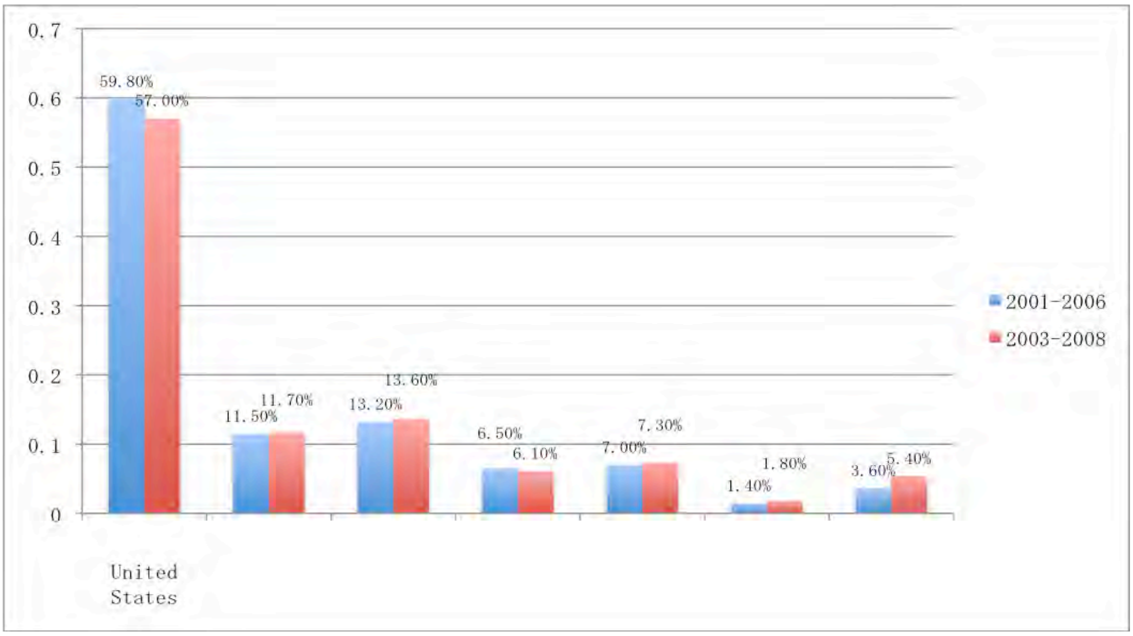
from WIPO, http://www.wipo.int/portal/index.html.en

Concerning overall research paper outputs, Japan has consistently produced an increasing number of papers. Its share in the world, however, has declined since 2000 both in the total production and in the highly cited papers category due to intensified global competition. Its

[1] WIPO, Intellectual Property Statistics, http://www.wipo.int/portal/index.html.en

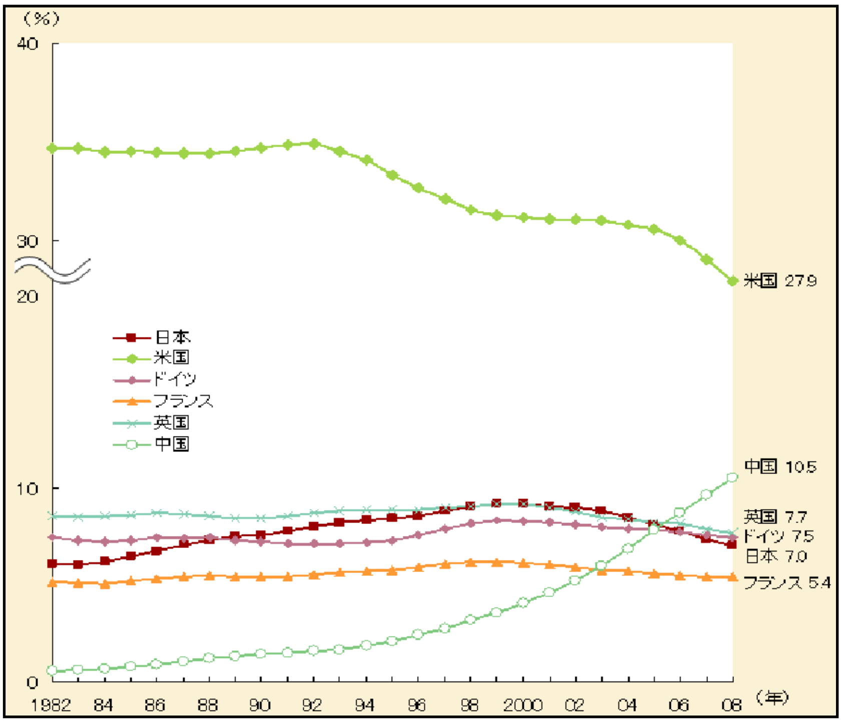
relative citation impact, however, has risen gradually (MEXT 2010) (see Figure 2.1.3, 2.1.4 and 2.1.5).

Figure 2.1.3. Share of highly cited papers (top 10%) by country



from MEXT, http://www.mext.go.jp/b_menu/hakusho/html/hpaa201001/detail/1296363.htm

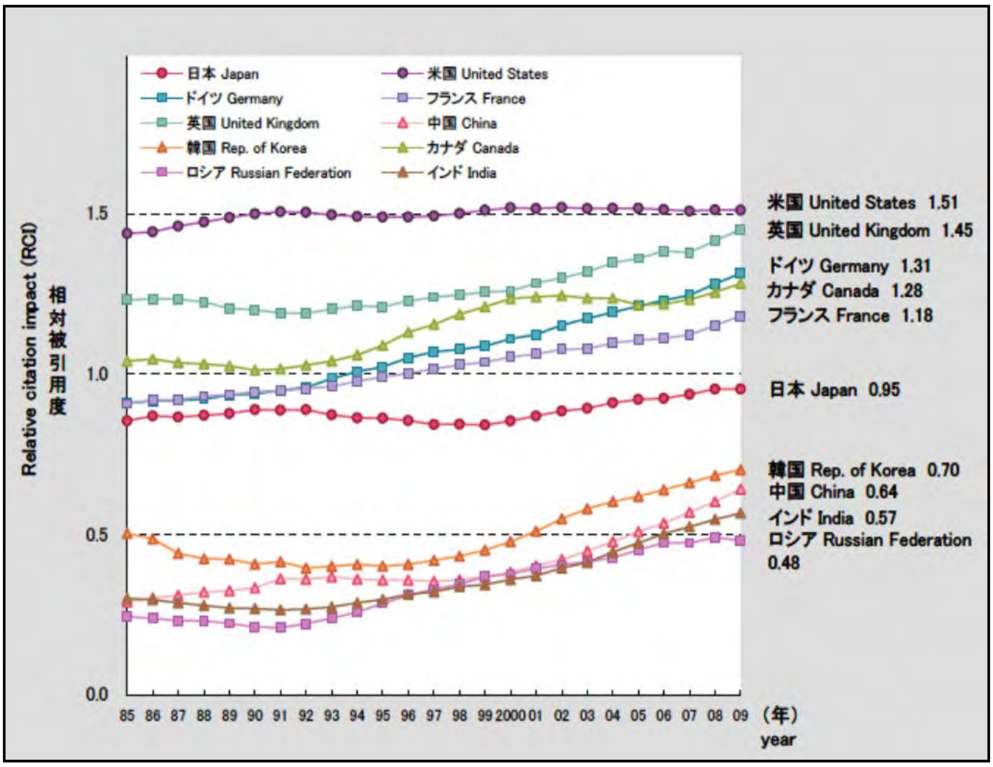
Figure 2.1.4. Share of total paper outputs by country



*red square (Japan), light green diamond (USA), pink diamond (Germany), orange triangle (France), blue 'x' (UK), green circle (China)

From MEXT, http://www.mext.go.jp/b_menu/hakusho/html/hpaa201001/detail/1296363.htm

Figure 2.1.5. Relative citation impact of scientific papers by country



From MEXT,
http://www.mext.go.jp/component/b_menu/other/__icsFiles/afieldfile/2011/07/12/1307510_3.pdf

2.2. Policy conditions for STEM promotion

After astounding growth during the late 1980s gave way to more sobering projections for the future of the Japanese economy, Japanese officials and policymakers recognized the haste with which necessary steps must be taken to ensure Japan's global competitiveness in the 21st century. The Japanese government, like those of many other industrial nations, was convinced that scientific and technological developments would form the basis for national financial stability, security and quality of life for its citizens (Holroyd and Coates 2007:34). Leaders acknowledged that at the crux of scientific and technological development lie innovation, and the road to promoting innovation required massive overhaul and reorganization of the educational system (Kitazawa 2010).

The sense of urgency for reform of science and technology law has been expressed by the Japanese government and scientific community as the emergence of 'research and development mega competition' in the 21st century.[2] According to Koichi Kitazawa

[2] For example, see Chapter 2 under the heading of "In the Era of Mega-Competition for Knowledge", published by the MEXT (2002). *Annual Report on the Promotion of Science and Technology 2002*

(2010:28-41), former president of the Japan Science and Technology Agency, this 'R&D mega competition' is in fact understood within the context of critical phase shifts in the development of international economic competition and, in particular, reflects changes in the nature of US-Japan bilateral economic and political friction since the 1970s. For Japanese businesses and industry, critical phase-shifts in international competition have continuously been forestalled: shifts from trade to production, from production to patent or intellectual property, and now from patent to research and development.[3]

Such forestalling of crucial competitive phase shifts and changes to the international economic circumstances that envelop Japan correspond to post-modern industrial restructuring and transition to a 'knowledge based economy', a notion often acknowledged in policy documents of Western governments. The understanding of ongoing industrial restructuring, however, is nuanced somewhat differently among Japanese business and scientific communities. For this report, it is sufficient to point out that there is a measure of national consensus: competitiveness of the national economy depends on the strength and capacity of research and development, and subsequently on human capital development. Education and educational institutions, from primary to tertiary and beyond, which nurture and train human resources to sustain the progress of technological innovation, therefore constitute a renewed political priority for contemporary Japan. Hence, STEM is placed within a framework of long-term national economic development and forms an integral part of such policy deliberations.

One example of key legislation emerging from such policy deliberations is the Science and Technology Basic Law (*Kagaku Gijutsu Kihon Hō,* or S&T Law) of 1995, which received unanimous cross-party support in the Diet. The law ushered in a series of reforms with significant, wide-reaching effects and defined mid- to long-term policies for science and technology across diverse ministries and sectors.

The object of the S&T Law is to attain a superior standard of science and technology that is expected to contribute not only to Japanese economic and societal development but also the

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[3] In the 1970s, amidst Japan's rapid economic progress through an increase in exports, the nation became enmeshed in a 'trade war' with the United States, evident in anti-Japan campaigns staged by American automakers protesting sharp increases in the number of Japanese cars exported to the US market. This phase of trade friction was followed by an era of 'technology friction' during the 1980s, when Japan was accused of free riding by not contributing to the development of basic science and technology but instead utilizing and profiting from others' achievements. This accusation was fueled by the Japanese semiconductor manufacturing's dominant share of the world market. An event symbolic of the technology friction characterizing the 1980s was the tying of the 1986 US-Japan Semiconductor Agreement after Japan became the world's largest semiconductor producer. Japan was accused of neglecting its obligation to contribute to basic science and technology and increasing market shares simply by refining technology targeting mass production. According to Kitazawa (2010), later in the 1990s when debates over patent and intellectual properties intensified, official policy was cast to make infringement punishable by indemnification, culminating in President Reagan's 1985 Trade Policy Action Plan, which included retaliation clauses and marked a new era of 'intellectual property' or 'pro-patent' competition. Now the economic competition is global rather than bilateral, and it centers on 'research and development'.

progress of global science and technology as the world builds toward a sustainable human society.[4] The key feature of the S&T Law is establishment of the Council for Science and Technology Policy headed by the Prime Minister. Although each ministry oversees implementation of individual measures, the council has authority over the general direction of the promotion of science and technology on the basis of five-year basic plans, thereby ensuring mid- to long-term planning and commitments (Kitazawa 2010:31-32).

3. Conditions of STEM

3.1. International comparison of primary and junior secondary STEM education (PISA and TIMSS)

Japan's performance in international comparisons of primary and junior secondary education, such as PISA and TIMSS, invoke a sense of impending crisis threatening the Japanese education system (see Table 3.1.1, 3.1.2 and 3.1.3).

Table 3.1.1. Japan PISA rank (score)

PISA	Mathematic Literacy	Scientific Literacy	Reading Literacy	Number of countries
2000	1 (557)	2 (550)	8 (522)	32
2003	6 (534)	4 (548)	14 (498)	41
2006	10 (523)	6 (531)	15 (498)	57
2009	9 (529)	5 (539)	8 (520)	65

from; PISA Database, http://www.oecd.org/pisa/pisaproducts/

Table 3.1.2. Japan TIMSS Mathematics rank/total countries (score)

Mathmatics	4th grade	8th grade
1995	3/26 (567)	3/41 (581)
2003	3/25 (565)	5/46 (570)
2007	4/36 (568)	5/48 (570)
2011	5/52 (585)	4/45 (570)

from TIMSS, http://timssandpirls.bc.edu/timss2011/index.html

[4] The Science and Technology Basic Law (Chapter 1, Article 1), Law No. 130 of 1995. Effective on November 15, 1995.

Table 3.1.3. Japan TIMSS Science rank/total countries (score)

Science	4th grade	8th grade
1995	2/26 (553)	3/41 (554)
2003	3/25 (543)	6/46 (552)
2007	4/36 (548)	3/48 (554)
2011	4/52 (559)	4/45 (558)

from TIMSS, http://timssandpirls.bc.edu/timss2011/index.html

In particular, so-called 'PISA shock' over the results from PISA 2003, in which Japan fell from 1st to 6th in Mathematic Literacy and 8th to 14th in Reading Literacy, reverberated throughout the country, forcing MEXT to recognize the decline in academic performance of Japanese students. According to a MEXT official, low reasoning ability rather than lack of knowledge was the most critical problem affecting Japanese students' performance on TIMSS.

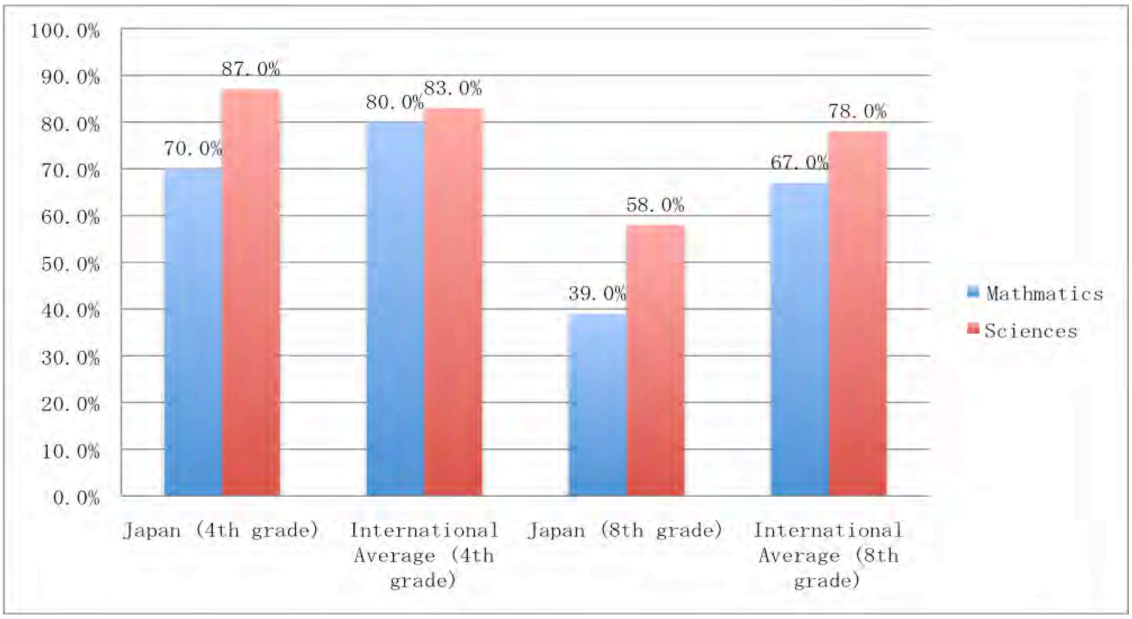
Poor performances in literacy on PISA and reasoning on TIMSS were attributed to weaknesses of Japanese STEM education and strongly influenced STEM education policy thereafter (Kudo 2012:2). MEXT introduced new special programs for improving literacy (MEXT 2005) and national surveys targeting primary and junior secondary education were conducted in the later half of the 2000s (Matsushita 2010:3-5). These reforms ultimately led to revision of the Curriculum Guidelines in 2008.

The reforms also led to improvement in performance on PISA 2009 (see Table 3.1.1). In particular, drastic improvement in Reading Literacy (from 15th in 2006 to 8th in 2009) was achieved through educational reform following PISA 2003, while less dramatic improvements in Mathematics and Scientific Literacy were also apparent (Matsushita 2010:3-5). The gap, however, between students who achieved advanced benchmarks and low benchmarks increased. Matsushita (2010) points out that features of traditional Japanese education such as a high standard and small disparity between levels of academic achievement had been lost by the late 2000s due to the decline of interests and motivations to learn, especially among students who achieved lower benchmarks (Matsushita 2010:4).

3.2. Japanese students' attitudes toward STEM subjects

TIMSS reports also portray the attitude of Japanese students toward STEM subjects. According to TIMSS 2007, for example, the proportion of Japanese students who claim to like mathematics and science is lower than the international average (see Figure 3.2.1).

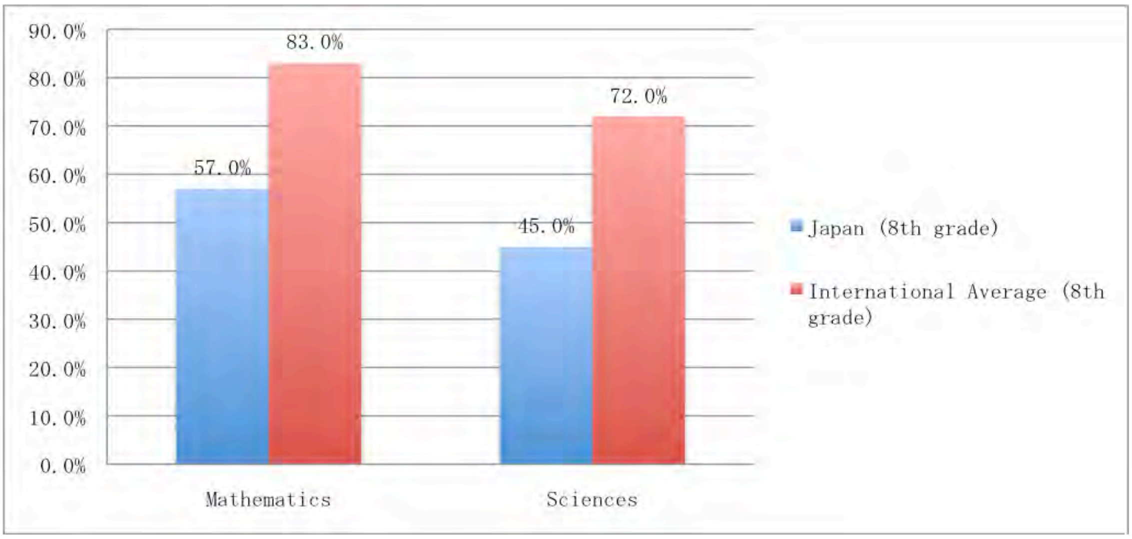
Figure 3.2.1. Proportion of Japanese students who like (agree a lot or agree a little) mathematics and science (TIMSS 2007)



from TIMSS (2007)

This result also illustrates that the decline between fourth grade and eighth grade in students' affinity for math and science subjects (-31% in mathematics and -31% in science) are remarkably large in comparison to other countries. In addition, almost half of students do not feel the study of mathematics and science is important to get the job they want (see Figure 3.2.2).

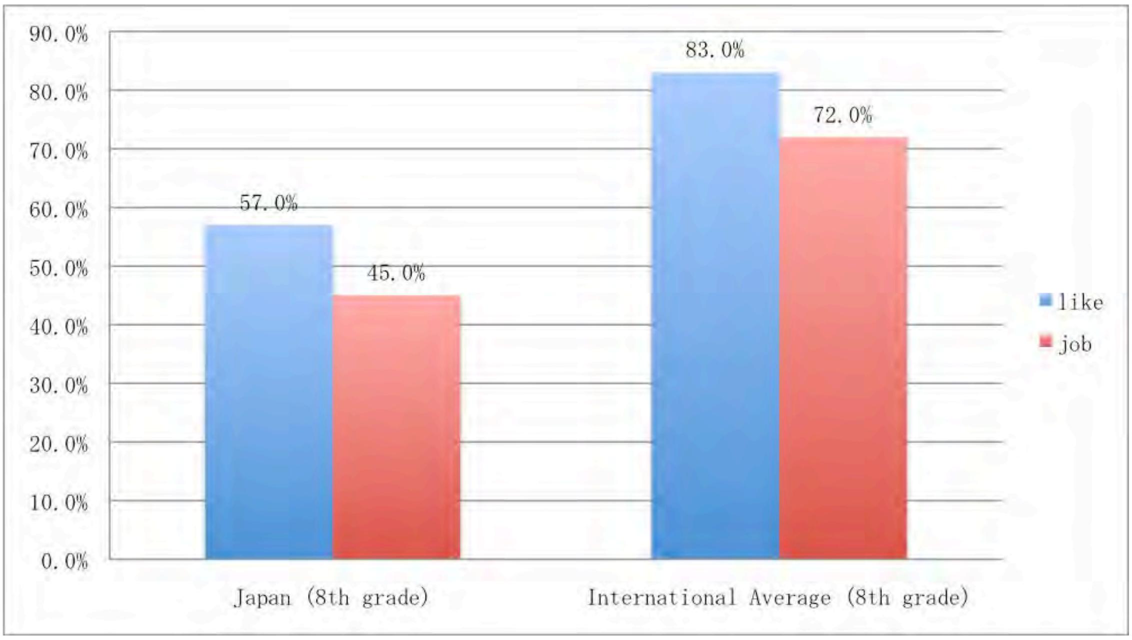
Figure 3.2.2. Proportion of Japanese eighth grade students who agree with the statement "I need to do well in mathematics and science to get the job I want" (TIMSS 2007)



from TIMSS (2007)

The gap between students who claim to like science and those who believe doing well in science is necessary to get the job they want is also larger than the international average (see Figure 3.2.3).

Figure 3.2.3. Gap between "I like science" and "I need to do well in science to get the job I want" (TIMSS 2007)

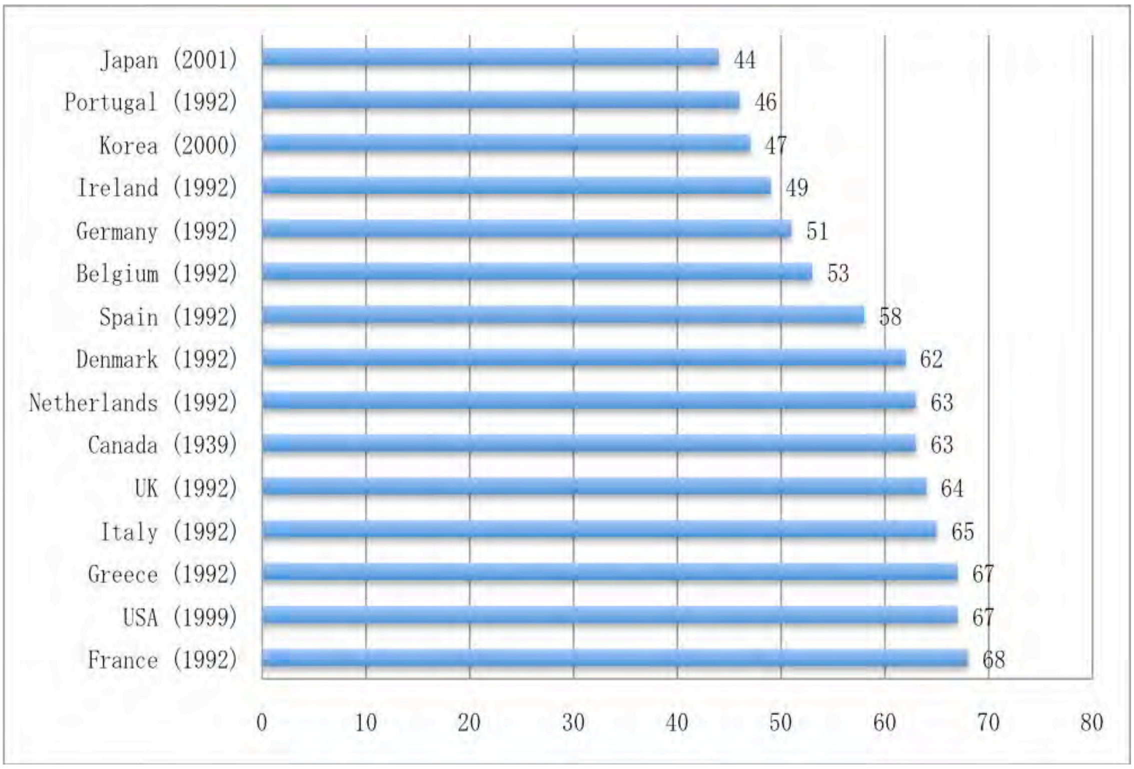


from TIMSS (2007)

TIMSS 2007 also reported that the number of hours spent studying at home by Japanese students (1 hour per day) is shorter than the international average (1.6 hours per day).

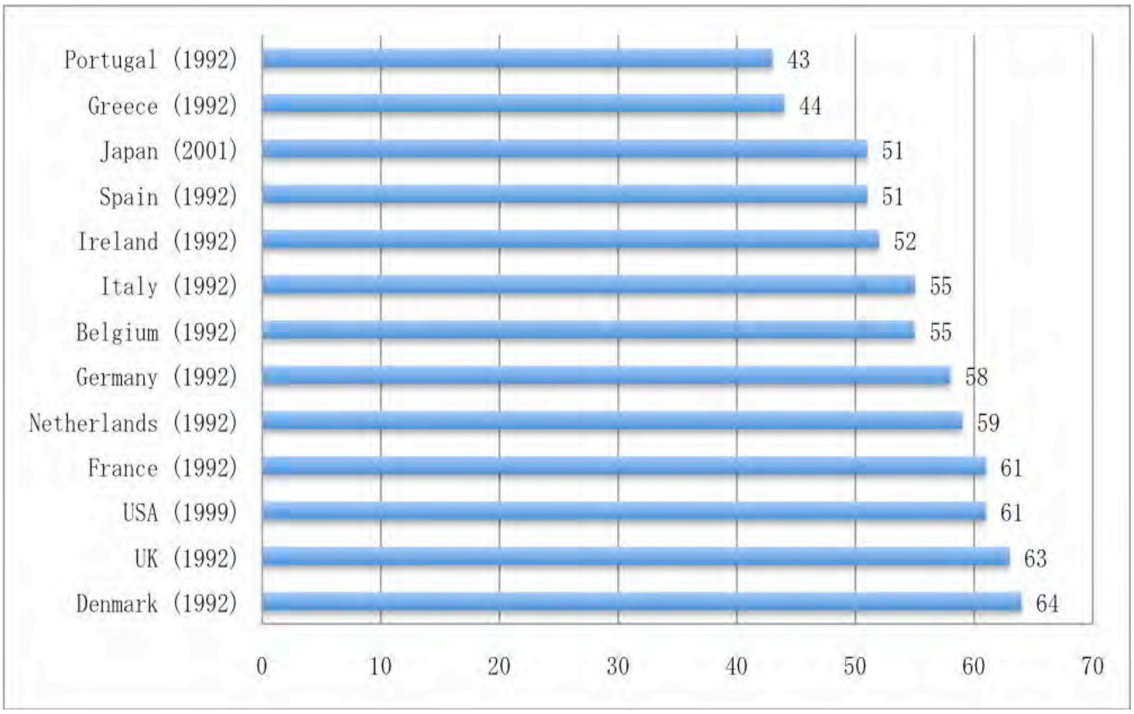
These results suggest that Japanese STEM education has failed to enhance Japanese students' interest in science and mathematics. At the same time, apathetic attitudes toward science constitute a grave problem plaguing Japanese society. A survey by the National Institute for Education Policy Research (NIER) shows that both the degree of interest in scientific discovery and the level of understanding of basic science and technology concepts in Japan are lower in comparison to other developed countries (NIER 2001) (see Figure 3.2.4 and 3.2.5).

Figure 3.2.4. International comparison of the degree of interest in scientific discovery



from NIER (2001), http://www.nistep.go.jp/achiev/abs/jpn/rep072j/rep072aj.html

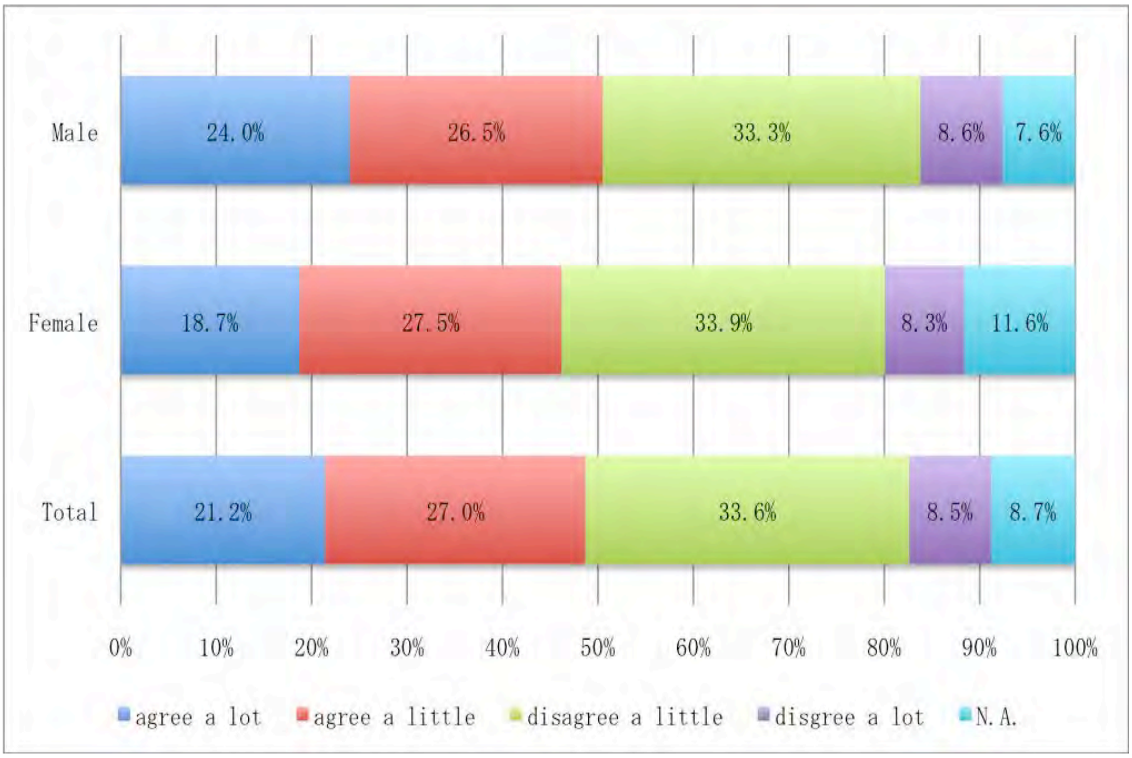
Figure 3.2.5. International comparison of the level of understanding of basic science and technology concepts



from NIER (2001),http://www.nistep.go.jp/achiev/abs/jpn/rep072j/rep072aj.html

In addition, according to a 2010 MEXT report (NIER 2010), less than 50 % of Japanese agree with the statement 'Japanese science education contributes to development of science literacy' (see Figure 3.2.6).

Figure 3.2.6. "Japanese science education contributes to development of science literacy"



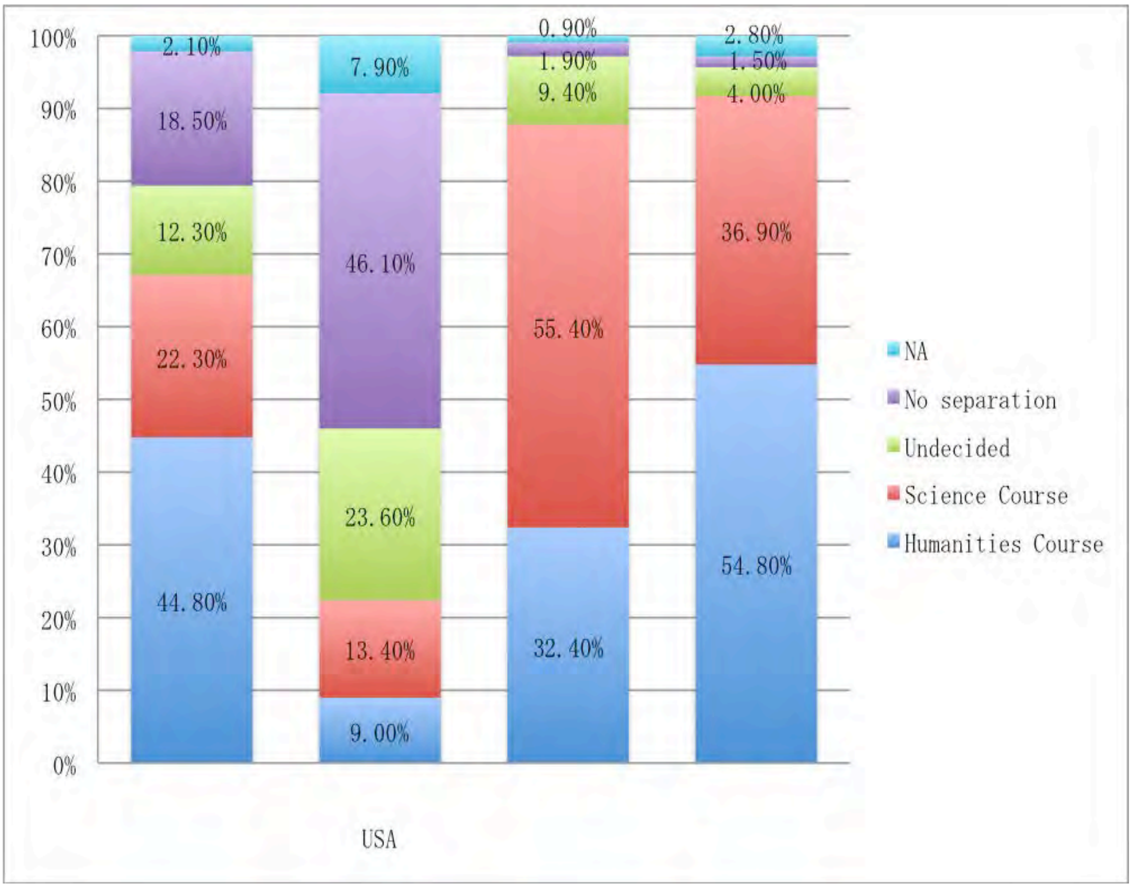
from NIER (2010), http://www8.cao.go.jp/survey/h21/h21-kagaku/2-1.html

As Ogura points out (Ogura 2007:17-18), reform of STEM education within compulsory education is critically important for improving science literacy in Japan.

3.3. Enrolment in STEM classes and courses in senior secondary and higher education

In the Japanese education system, students at the senior secondary level choose whether to follow a science course track (with emphasis on mathematics and science) or humanities course track (with emphasis on Japanese and social studies). The two tracks of study, science and humanities, are based on separate curricula and only science course track students are required to take advanced mathematics and science classes. According to a survey by the Japanese Youth Research Institute in 2005 (Japanese Youth Research Institute 2005), the number of students in Japan who belong to a humanities course track is considerably greater than those who belong to a science course track, in contrast to other countries such as China (see Figure 3.3.1).

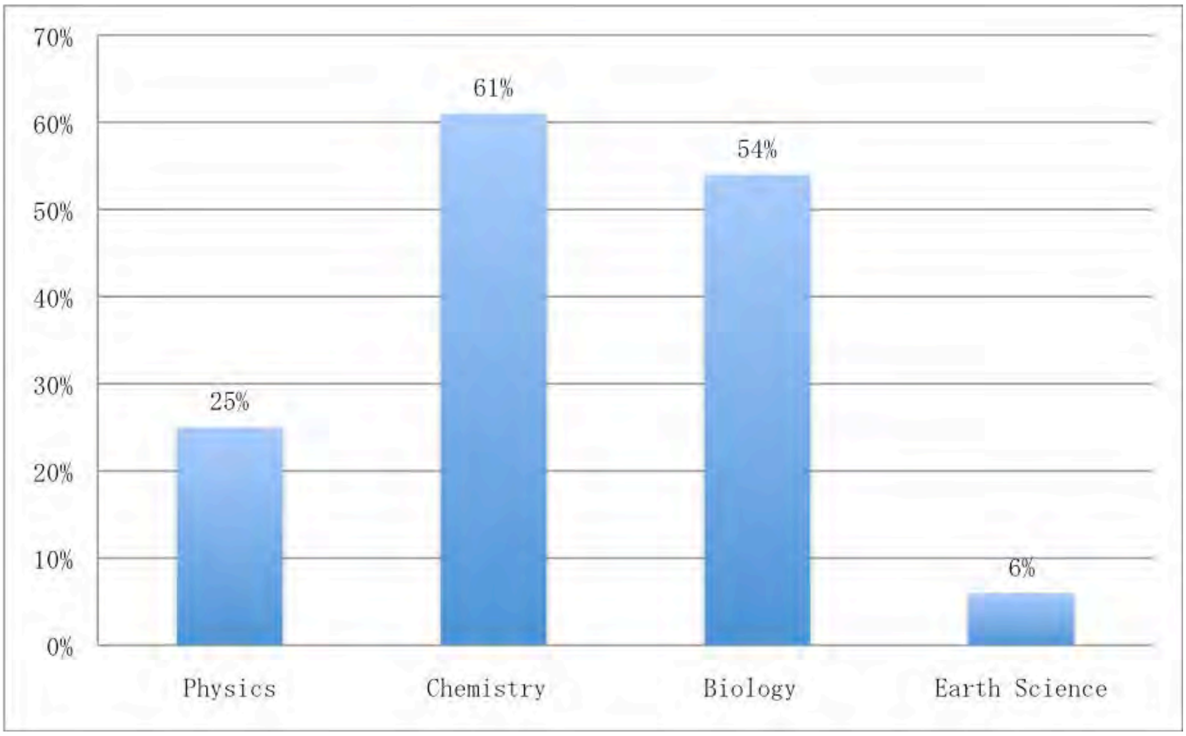
Figure 3.3.1. Ratio of students who belong to a science or humanities course track in senior secondary education



from Japan Youth Research Institute (2005)

In addition, the percent of students who enrol in STEM classes has steadily decreased over the decades between 1970 and 2000. Until the 1970s, Japanese high school students who aspired to pursue higher education were required to take four science subjects: Physics, Chemistry, Biology and Earth Science. Following revision of the Curriculum Guidelines in 1982, however, students were only required to take two out of the four science subjects. This led to a decrease in the ratio of enrolments in science subjects in senior secondary education. In particular, the percent of students who enroled in Physics dramatically decreased from 80-90% in the 1970s to 20% in the 2000s (The Japan Machinery Federation 2012:32) (see Figure 3.3.2).

Figure 3.3.2. Ratio of enrolment in science subjects in Japanese senior secondary education (in 2002)



from Ogura (2007), p.11.

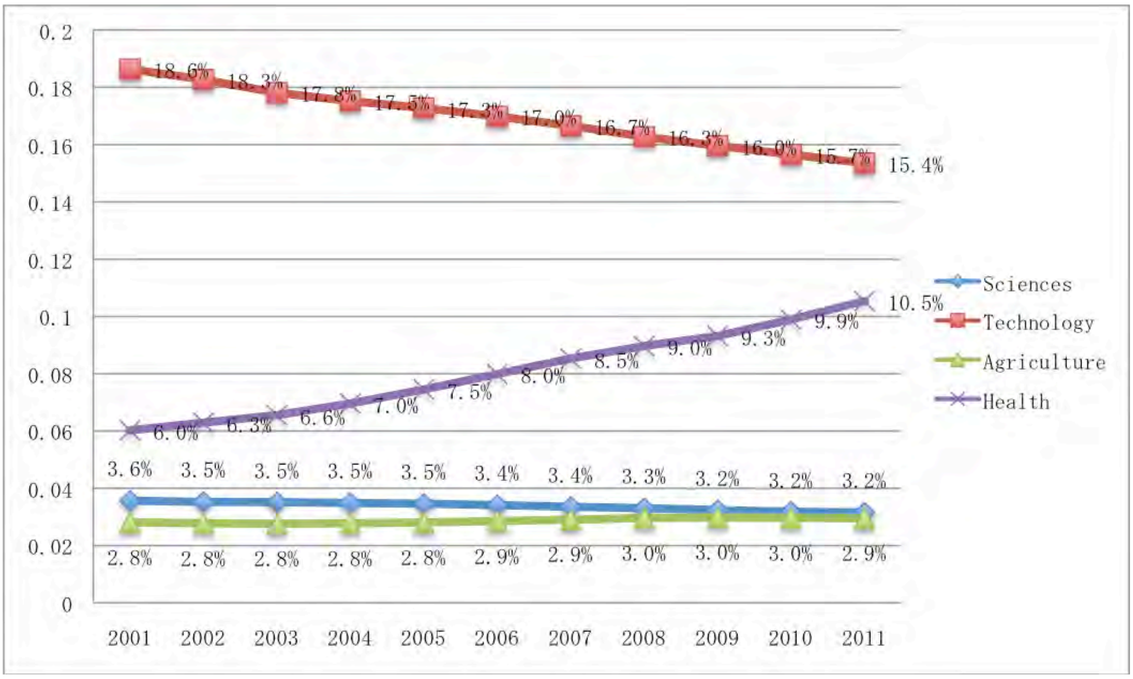
The system of university entrance examinations has also led to the decline of scholastic ability in science and mathematics. As stated above, the Curriculum Guidelines requires students to take at least two science subjects from a total of four. However, most national universities require that students who aspire to enter humanities faculties take only one science subject, and many private universities require humanities course students to take entrance exams for Japanese, English and Social Sciences only. Many critiques have been made of the present entrance examination system as well as revisions to the Curriculum Guidelines over the last quarter of the twentieth century, claiming they have led to the decline of basic scholastic achievement in science and mathematics. For instance, Nishimura denounces the present examination system as shifting emphasis away from written examinations and onto examinations based on interviews and recommendations, including self-recommendations (Okabe, Tose and Nishimura 1999:12-15). This created a widespread scandal in some high schools preparing students to enter university in the latter half of the 2000s, when it was discovered that some graduates had failed to complete required subjects not related to university entrance examinations.[5] This all told, the study hours dictated by the Curriculum Guidelines for senior secondary education continued to decrease up to the revision of the

[5] For example, below URL (in Japanese) shows an instruction given by the Board of Education, Hokkaido to high schools in the area, concerning how to deal with such a shortage in required subjects: http://www.dokyoi.pref.hokkaido.lg.jp/hk/kki/grp/02/imeituti061102.pdf, viewed 15 November 2012.

Curriculum Guideline in 2008.

The ratio of undergraduate students who belong to STEM-related faculties, namely technology and sciences, has steadily decreased since 2001 (see Figure 3.3.3).

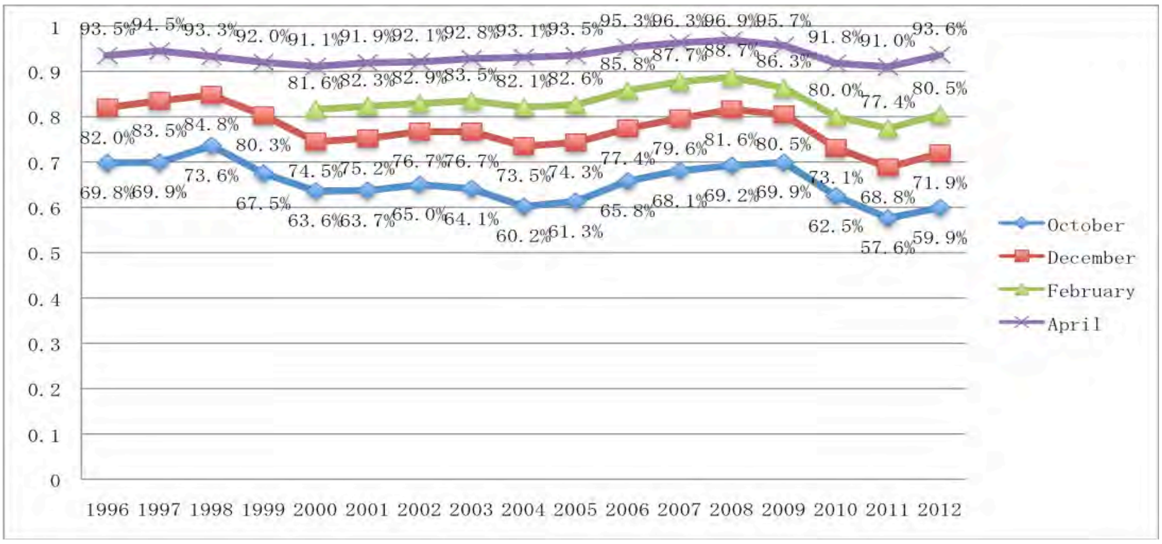
Figure 3.3.3. Ratio of undergraduate students in STEM faculties



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

On the other hand, the ratio of students who belong to health faculties has seen remarkable growth during this same period. Since the latter half of the 1990s, after the collapse of the bubble economy, the unemployment ratio has risen alongside intensification of undergraduates' job hunt. Whereas in the past the ratio of undergraduate students who secured employment early in their fourth year of university (October) was high, the ratio securing employment later in their fourth year is growing (see Figure 3.3.4), thus compelling students to start their job hunt earlier and earlier, often beginning in the third year of university.

Figure 3.3.4. Ratio of undergraduate students who received tentative job offers

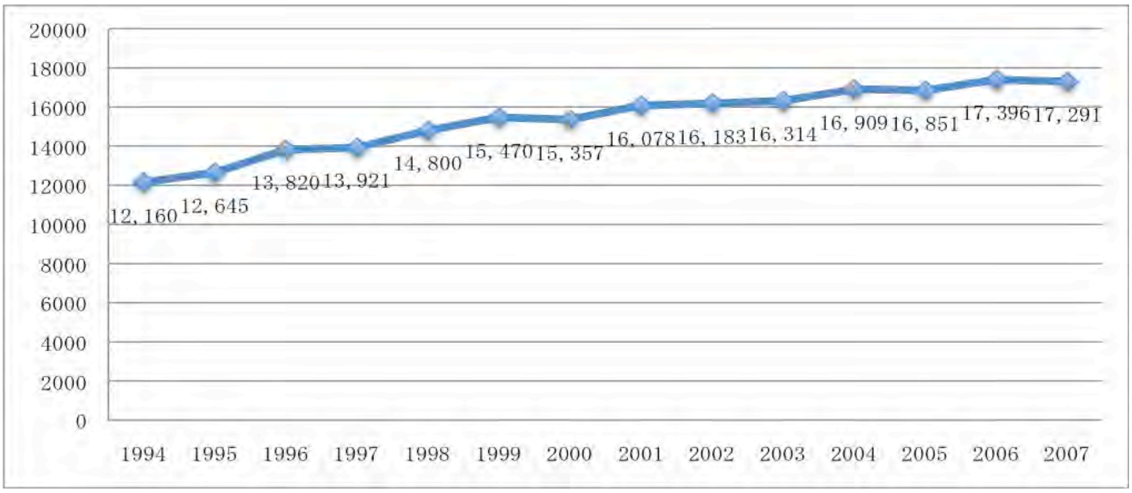


from Ministry of Health, Labour and Welfare, http://www.mhlw.go.jp/toukei/youran/indexyr_c_2.html

In addition, the growing aging population within Japanese society appears to have encouraged high school students to enter majors more closely connected to job training and certification.

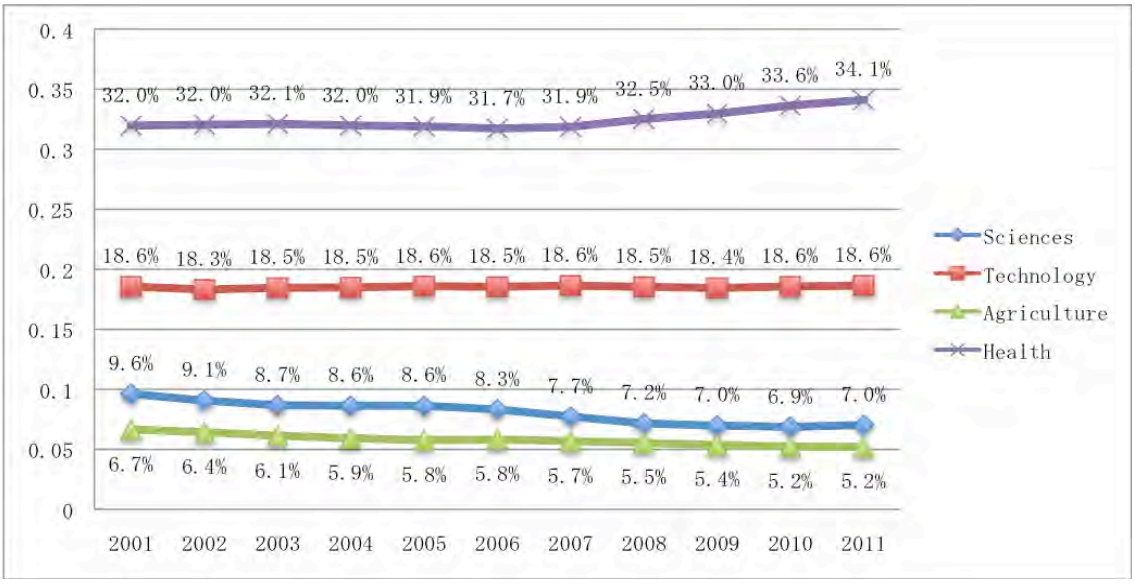
Although the total number of doctoral degrees awarded in science and technology areas has steadily increased (see Figure 3.3.5), due to the expansion of graduate school education and reforms instituted through the S&T Basic Law, the ratio of doctoral course students in STEM faculties such as Technology, Science and Agriculture has either leveled off or decreased (see Figure 3.3.6).

Figure 3.3.5. Number of doctoral degrees in science and technology fields



from National Science Board, National Science Foundation of the United States, Science and Engineering Indicators, http://www.nsf.gov/statistics/seind12/

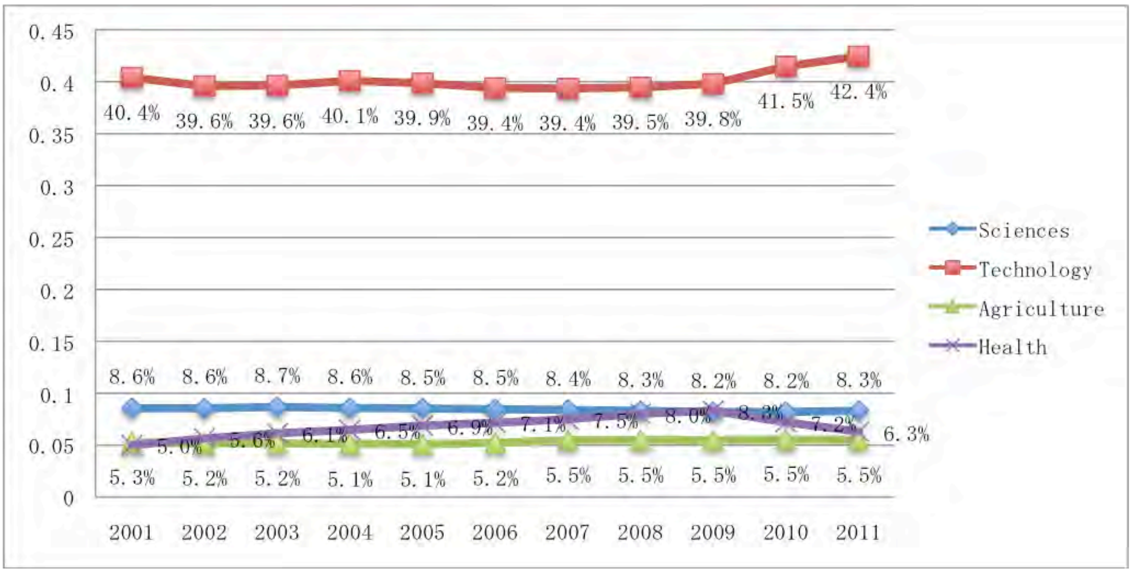
Figure 3.3.6. Change in the ratio of doctoral course students belonging to STEM faculties



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

Contrastingly, the ratio of master's course students in Technology has increased and remained stable in Science as well as Agriculture (see Figure 3.3.7).

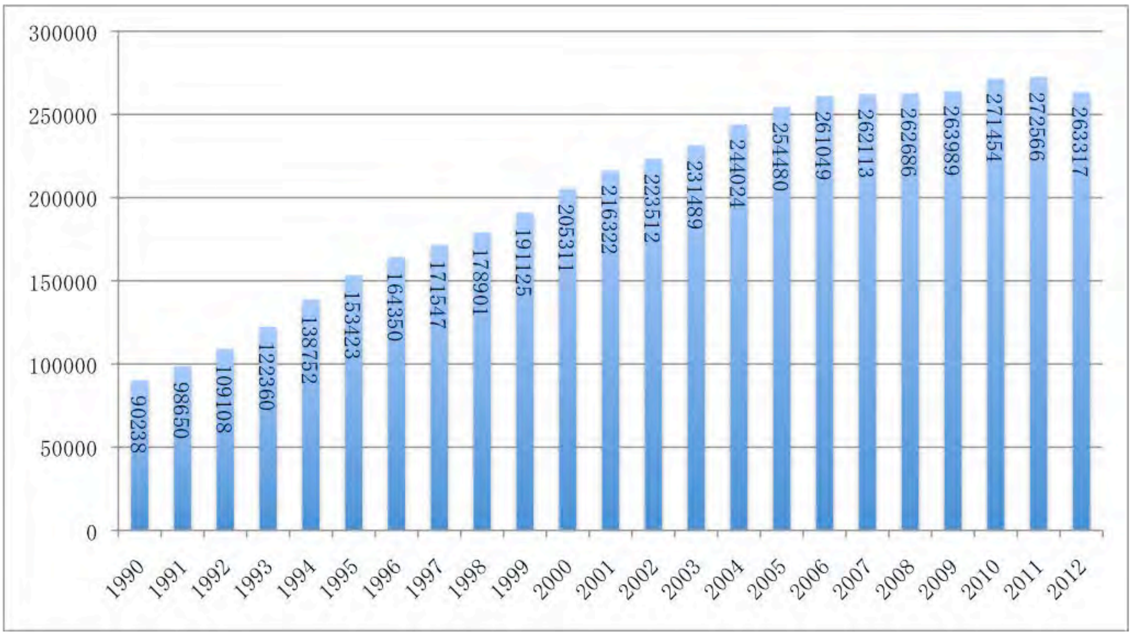
Figure 3.3.7. Change in the ratio of master's course students belonging to STEM faculties



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

Most students in technology-related faculties go on to graduate school if they want to get jobs outside of universities. This not only reflects the expansion of graduate school education (the number of postgraduate students has increased nearly threefold over the past two decades: see Figure 3.3.8), but also explains why many Japanese companies are able to demand workers who have gained substantial knowledge and skills during their postgraduate education preparing them to immediately enter the workforce.

Figure 3.3.8. Number of postgraduate students

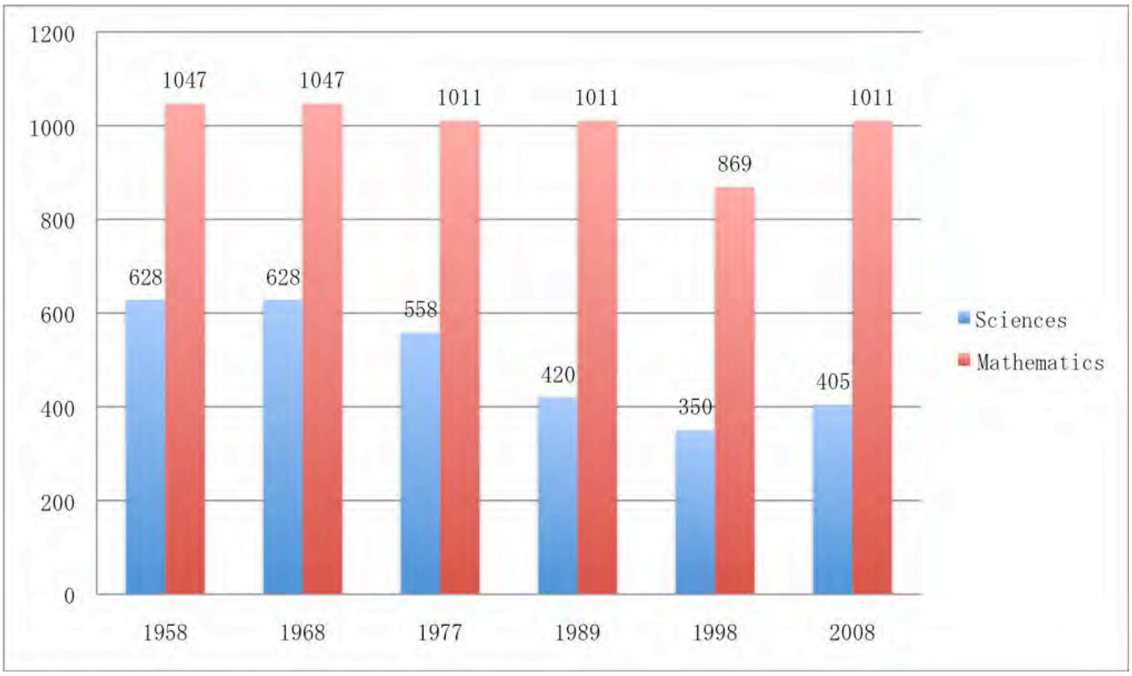


from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

3.4. Number of STEM classes and teachers

The Curriculum Guidelines of 1998 significantly decreased the number of school hours of STEM subjects in Japanese compulsory education. Promoting the idea of '*yutori* education', the 1998 Guidelines reduced the school hours and contents of mathematics and science curricula to approximately 150 hours for mathematics in primary education and 50-70 hours for junior secondary mathematics as well as primary and junior secondary science (see Figure 3.4.1 and 3.4.2).

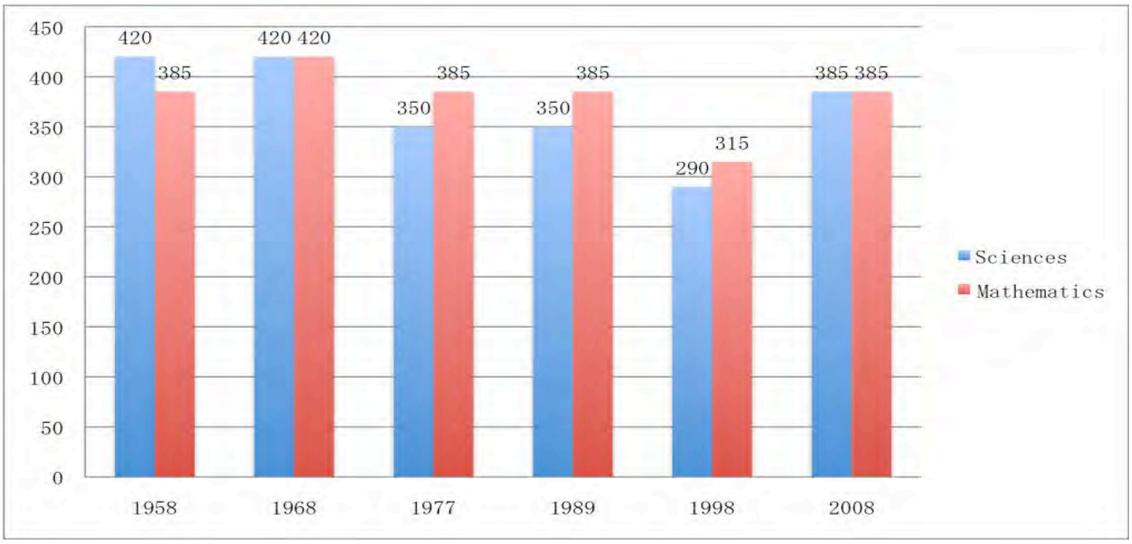
Figure 3.4.1. Total study hours of Mathematics and Sciences in Japanese primary education



from MEXT, http://www.mext.go.jp/a_menu/shotou/new-cs/youryou/index.htm,

and NIER (2005), http://www.nier.go.jp/kiso/sisitu/siryou1/2-02.pdf

Figure 3.4.2. Total Study Hours of Mathematics and Sciences in Japanese junior secondary education



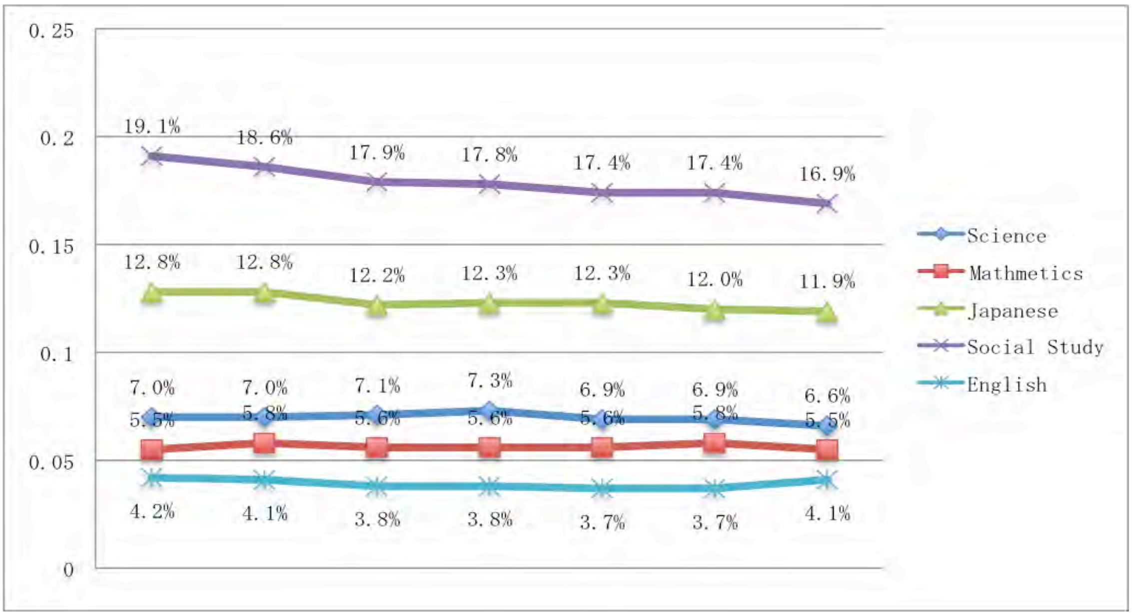
from MEXT, http://www.mext.go.jp/a_menu/shotou/new-cs/youryou/index.htm,

and NIER (2005), http://www.nier.go.jp/kiso/sisitu/siryou1/2-02.pdf

The contents of the curricula were also reduced by 30% and simplified. However, a variety of severe criticisms of the 1998 Curriculum Guidelines appeared in the early 2000s, which were compounded by the 'PISA shock' phenomenon following publication of the 2003 PISA results. In response, the Curriculum Guidelines of 2008 increased the study hours of mathematics and science up to the standard of 1988. Notably, the study hours of science in junior secondary education were increased by nearly one-third (95 hours).

In addition, the quantity and quality of primary school teachers who possess in-depth knowledge of science and mathematics constitutes a critical agenda of STEM education in Japan. Teachers at the primary level generally teach all subjects, and most primary school teachers possess not only a primary teaching license but also a junior secondary teaching license, which are divided according to subject. The ratio of primary education teachers who possess junior secondary teaching licenses in Science (6.6%) or Mathematics (5.5%) is far less than those who possess junior secondary teaching licenses in Japanese (11.9%) or Social Studies (16.9%) (see Figure 3.4.3).

Figure 3.4.3. Ratio of teachers in primary education who possess a license to teach junior secondary education



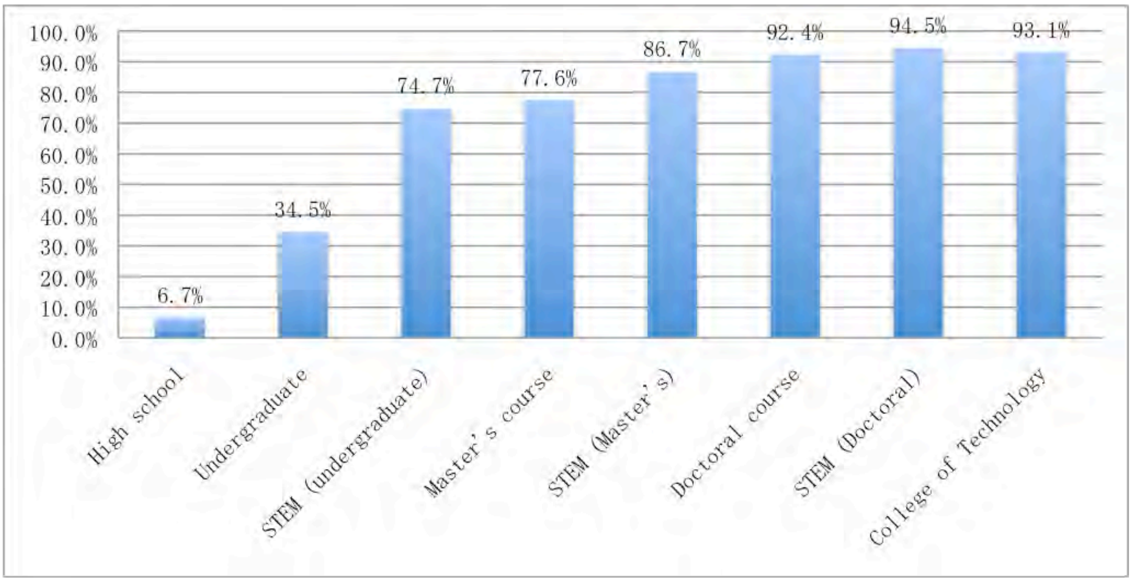
from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/GL08020101.do?_toGL08020101_&tstatCode=000001016172&requestSender=dsearch

According to a MEXT survey, in order to address this situation, approximately 30% of public schools in grades 4-6 place specialized science teachers, rather than all-subject teachers, in charge of science classes.

3.5. Careers of STEM students after graduation

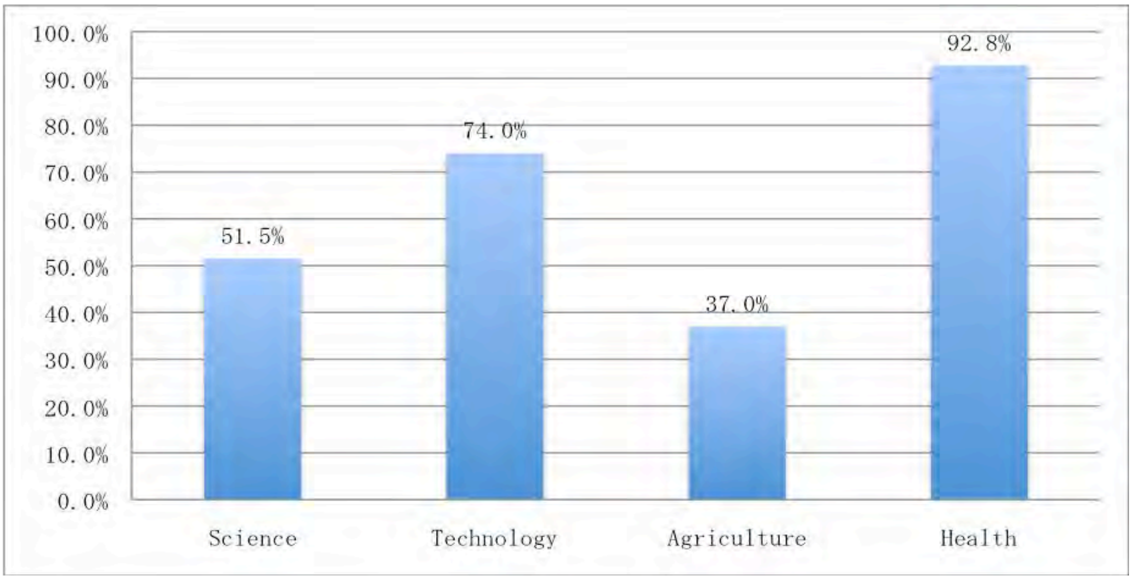
The ratio of STEM undergraduates who get professional or technical work after graduation is almost double that of all undergraduates (see Figure 3.5.1). Furthermore, among STEM undergraduates, the ratio of those who get professional or technical work is particularly high for Technology (74%) and Health (92.8%) faculties (see Figure 3.5.2).

Figure 3.5.1. Ratio of new employees entering professional or technical jobs in 2012 by level of education



from Basic Survey on Education ,http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

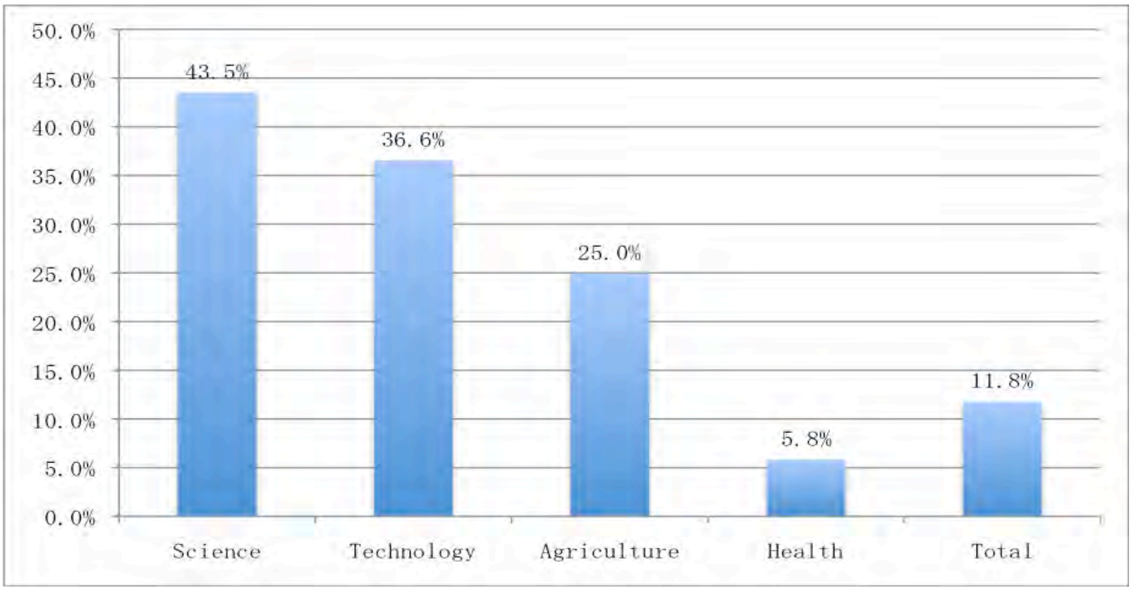
Figure 3.5.2. Ratio of new employees entering professional or technical jobs in 2012 at the undergraduate level by major



from Basic Survey on Education,http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

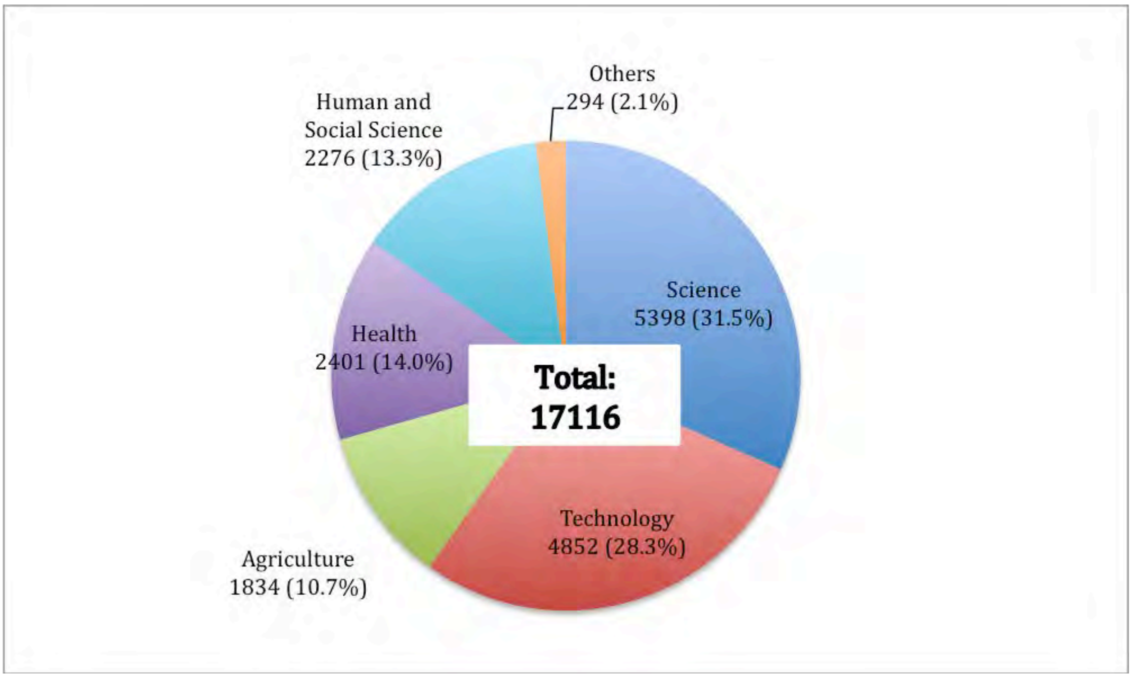
On the other hand, as mentioned above, the ratio of STEM undergraduates who go on to postgraduate programs is greater than that for Humanities or Social Science undergraduates (see Figure 3.5.3). This circumstance has led to an increase in STEM postdoctoral fellows. For example, in 2009, Science and Technology postdoctoral fellows accounted for over half of the total (see Figure 3.5.4.), despite the ratio of doctoral course students belonging Science and Technology faculties being relatively low (7.0% and 18.9% respectively; see Figure 3.3.6).

Figure 3.5.3. Ratio of undergraduate students who went on to postgraduate programs in 2012 by major



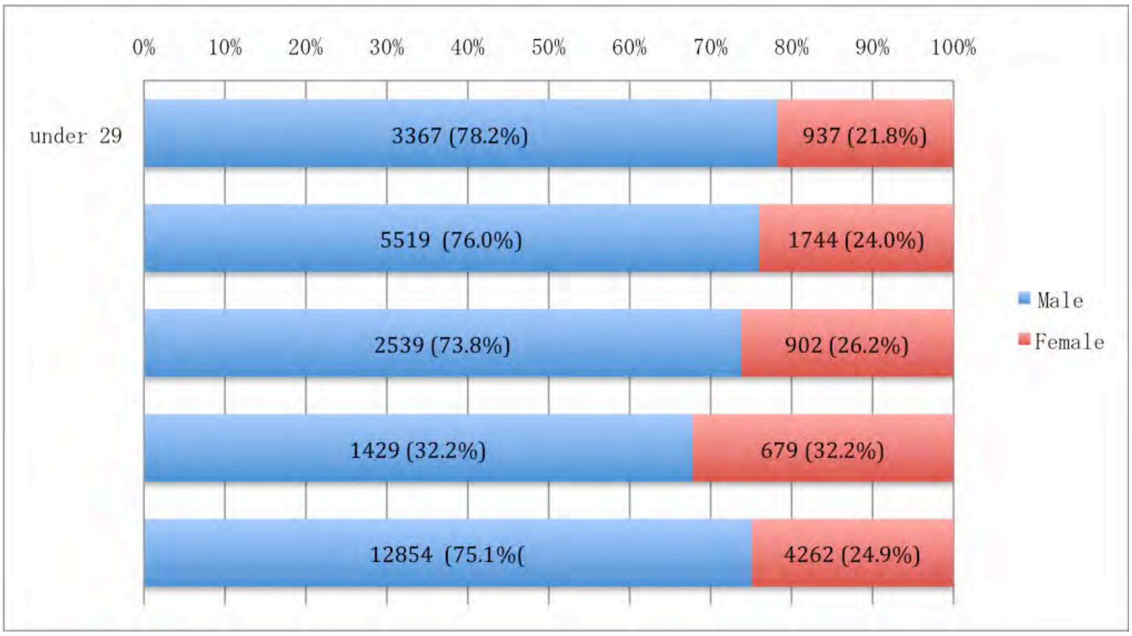
from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

Figure 3.5.4. Ratio of postdoctoral fellows by area (2009)



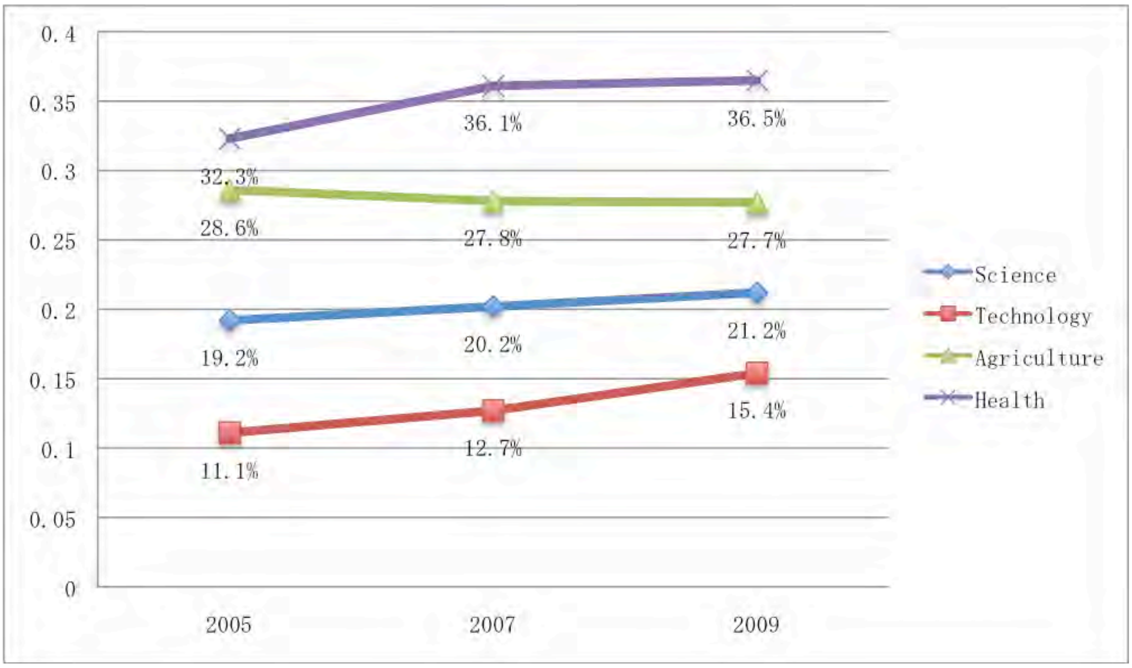
from NISTEP (2011a), http://www.nistep.go.jp/achiev/ftx/jpn/mat202j/pdf/mat202j.pdf

Figure 3.5.5. Ratio of postdoctoral fellows by age and gender (2009)



from NISTEP (2011a) http://www.nistep.go.jp/achiev/ftx/jpn/mat202j/pdf/mat202j.pdf

Figure 3.5.6 Ratio of female postdoctoral fellows by discipline

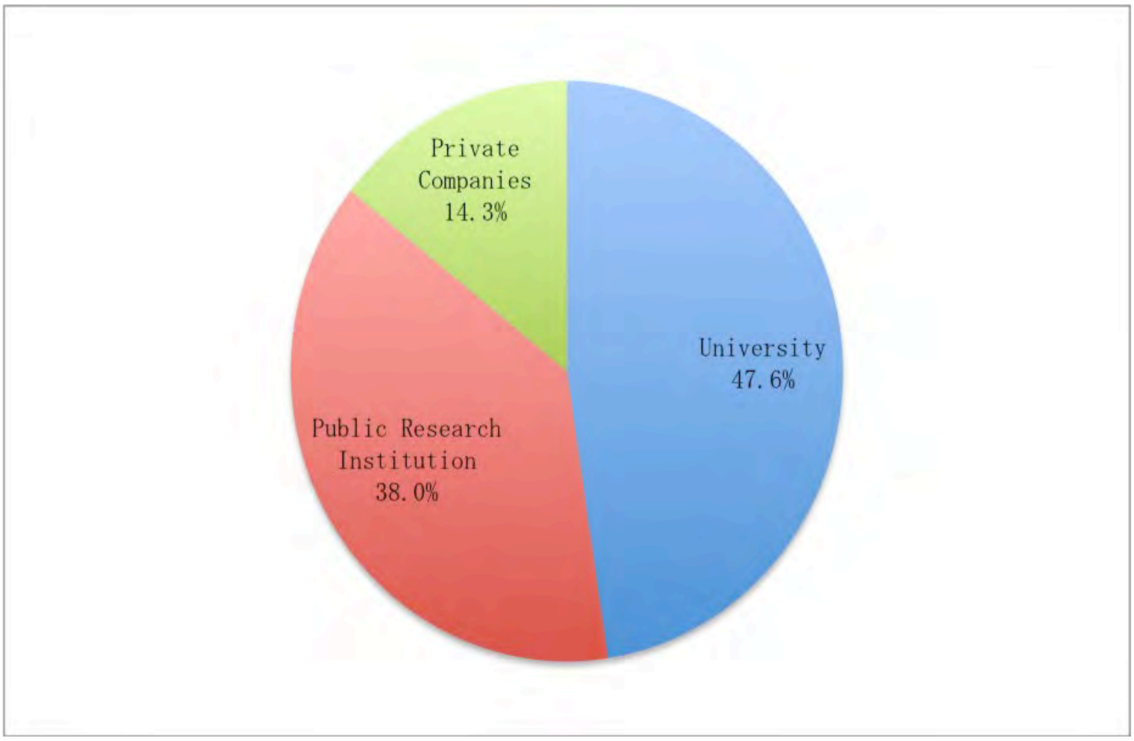


from NISTEP (2011a) http://www.nistep.go.jp/achiev/ftx/jpn/mat202j/pdf/mat202j.pdf

This suggests that graduates of doctoral courses in Science and Technology are less likely to secure employment after graduation compared to graduates of other faculties. Furthermore, the advancement in aging of postdoctoral fellows (see Figure 3.5.5) and the increase in percentage of female postdoctoral fellows pose critical issues. Figure 3.5.6 shows that 32.4% of all postdoctoral fellows are above 35 years old, while the percentage of female postdoctoral fellows above 35 years old is 37.1% (NISTEP 2011a:14). Although approximately 60% of postdoctoral fellows acquired posts as university faculty members or researchers at public institutions, 24.2% of postdoctoral fellows remained post-doctors between 2002 and 2006 (NISTEP 2011a:18-19).

On average, doctoral course graduates are much less likely to be employed by private companies than by universities or public research institutions (see Figure 3.5.7).

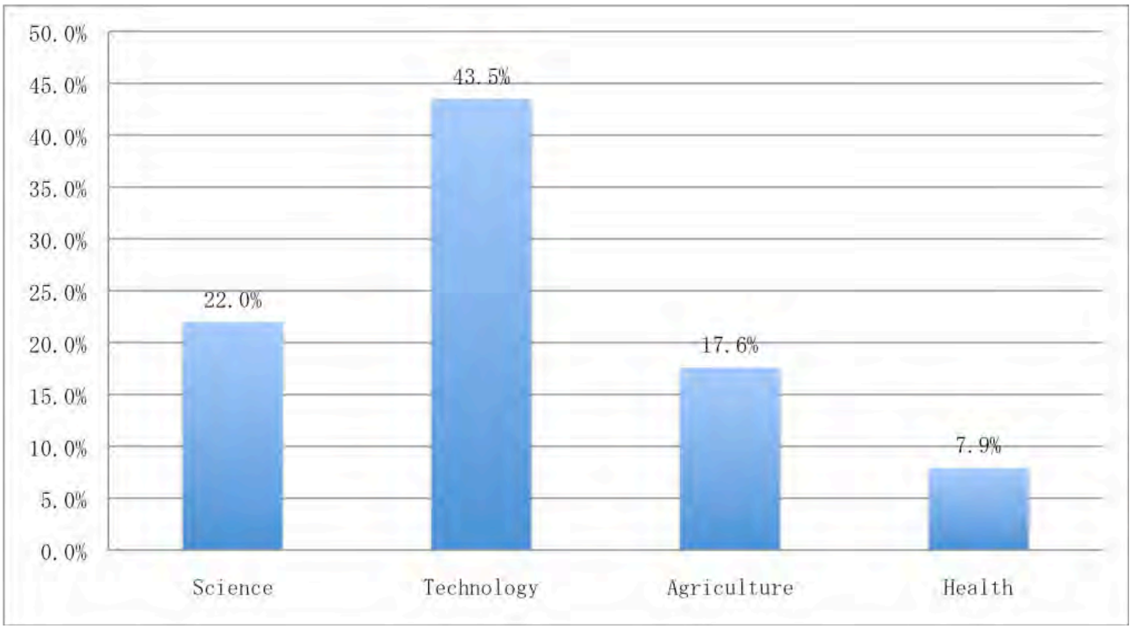
Figure 3.5.7. Employment of doctoral graduates from 2002 to 2006



from Misu, Horoiwa and Chayama (2010), http://hdl.handle.net/11035/923f

According to a survey by the National Institute of Science and Technology Policy (NISTEP 2011b), only 24.1% of Japanese private companies employ doctoral course graduates, while 86.2% employ master’s course graduates. At the same time, by discipline, the percentage of Technology doctoral graduates who obtain jobs in private companies (43.5%) is extremely high in contrast to Sciences (22.0%), Agriculture (17.6%) and Health (7.9%) (NISTEP 2011a:12) (see Figure 3.5.8). In addition, researchers who secure academic jobs at universities or public institutions rarely transfer to the private sector. However, researchers in chemistry have relatively higher mobility in comparison to those in biology due to the fact that chemistry-related industries in Japan have developed to a much greater extent (NISTEP 2011a: vii).

Figure 3.5.8. Ratio of doctoral graduates who obtained jobs in private companies from 2002 to 2006

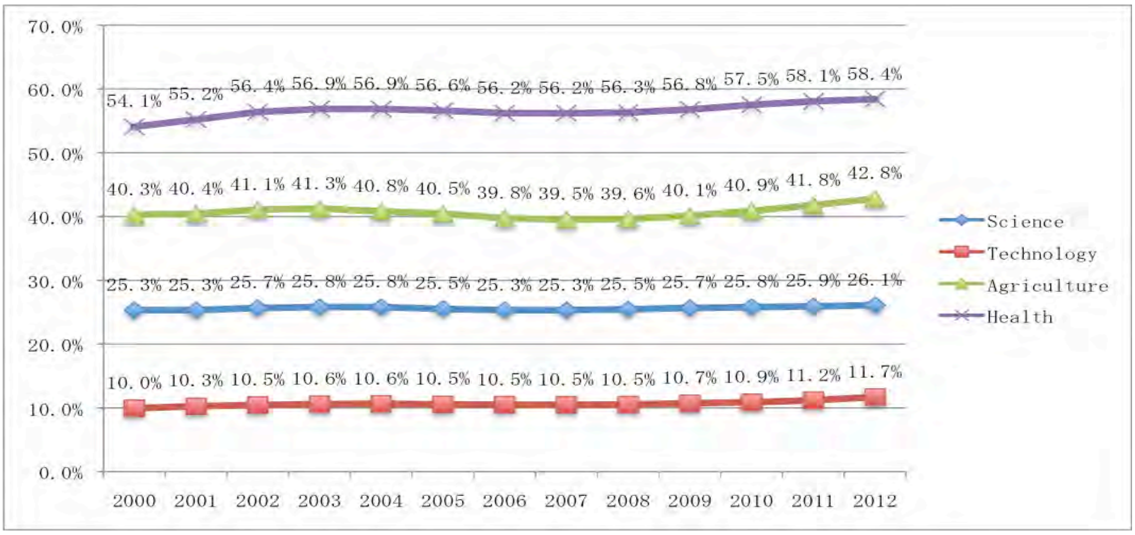


from Misu, Horoiwa and Chayama (2010), http://hdl.handle.net/11035/923f

3.6. Women in STEM education and careers

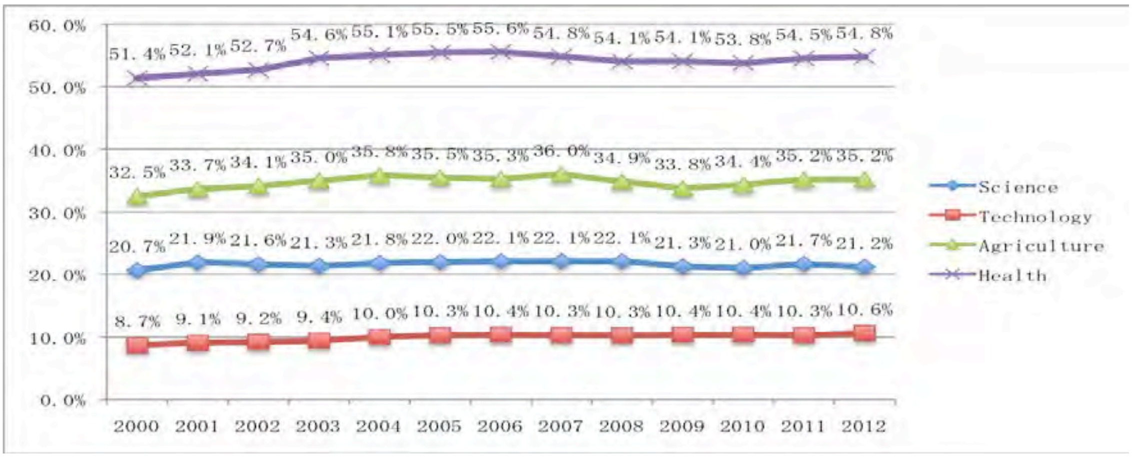
The participation of female students in STEM-related courses is relatively lower than that of male students. In 2012, the ratio of female students belonging to technology undergraduate programs (see Figure 3.6.1) and master's courses (see Figure 3.6.2) was approximately 10%. On the other hand, there has been a notable increase over the past decade in the ratio of female students in doctoral courses across all STEM disciplines (see Figure 3.6.3).

Figure 3.6.1. Ratio of female students belonging to STEM faculties (undergraduate level)



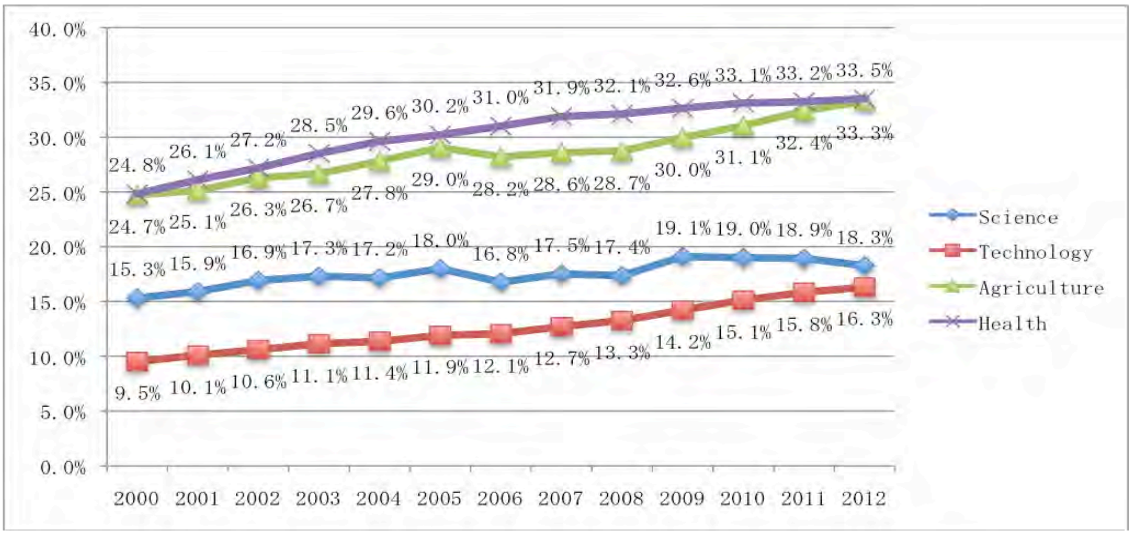
from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

Figure 3.6.2. Ratio of female students belonging to STEM faculties (master's course level)



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

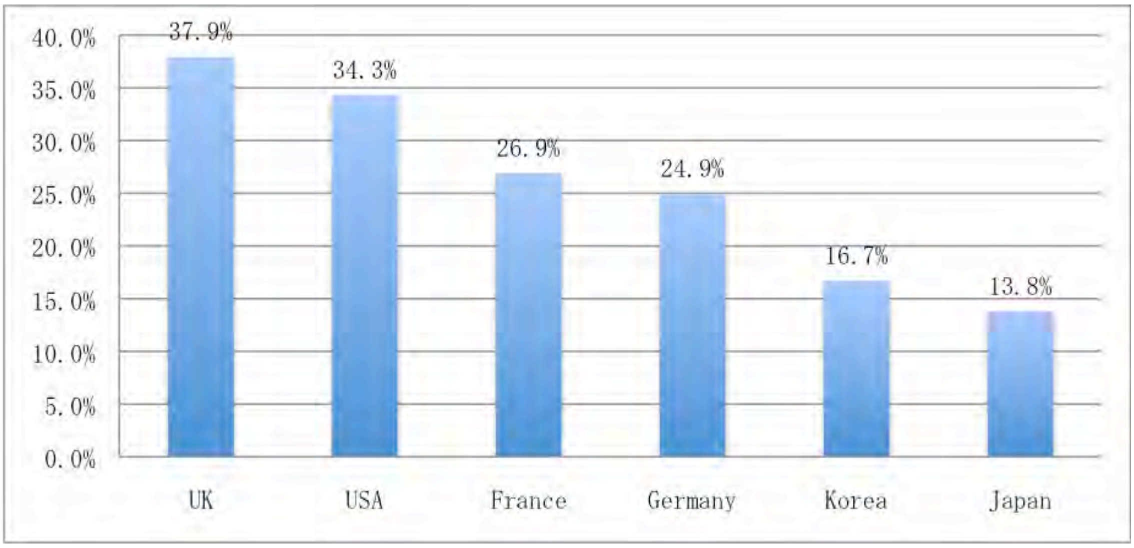
Figure 3.6.3. Ratio of female students belonging to STEM faculties (doctoral course level)



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

Despite this trend, the small ratio of female researchers in Japan, particularly when compared to other countries, remains a critical issue (see Figure 3.6.4).

Figure 3.6.4. Ratio of female researchers in developed countries



from MEXT (2012),

http://www.mext.go.jp/component/b_menu/other/__icsFiles/afieldfile/2012/01/10/1314895_8.pdf

According to Nihon Keizai Shimbun (21 August 2012), Japan's leading business and economics newspaper, the representation of female researchers in Japan is 'distinctively low' and lags far behind other advanced nations. Female researchers in universities, corporations, and public research institutions accounted for 13.8% of the total (including a limited number of those in humanities and social sciences) in 2010, a conservative 6 percentage point increase over the past two decades, but still far behind Russia (41.7%) or the United States (34.3%). Although more than 24% of university researchers are now women, only 7.6% of researchers in companies are female. Overall, two-thirds of male researchers work in companies, while only about one-third of their female counterparts hold positions in the corporate sector (Nihon Keizai Shimbun, 21 August 2012).

The same article also points out that female 'engineers' are minorities to an even greater degree, comprising a meager 8.6% of all engineers, though the ratio of female engineers has increased from the 1970s (female engineers accounted for only 1.4% in 1970) (Kobayashi 2011:230-231). According to a 2005 census,[6] the ratio of female engineers in metal engineering and civil engineering did not reach 5% (see Table 3.6.1). The low ratio of female students in technology undergraduate courses (4%) and colleges of technology are likely contributing factors (16.2%) (see Figure 3.6.5).

[6] Japanese Government e-Stat, National Census 2005, http://www.e-stat.go.jp/SG1/estat/GL08020103.do?_toGL08020103_&tclassID=000001029564&cycleCode=0&requestSender=search, viewed 18 January 2013.

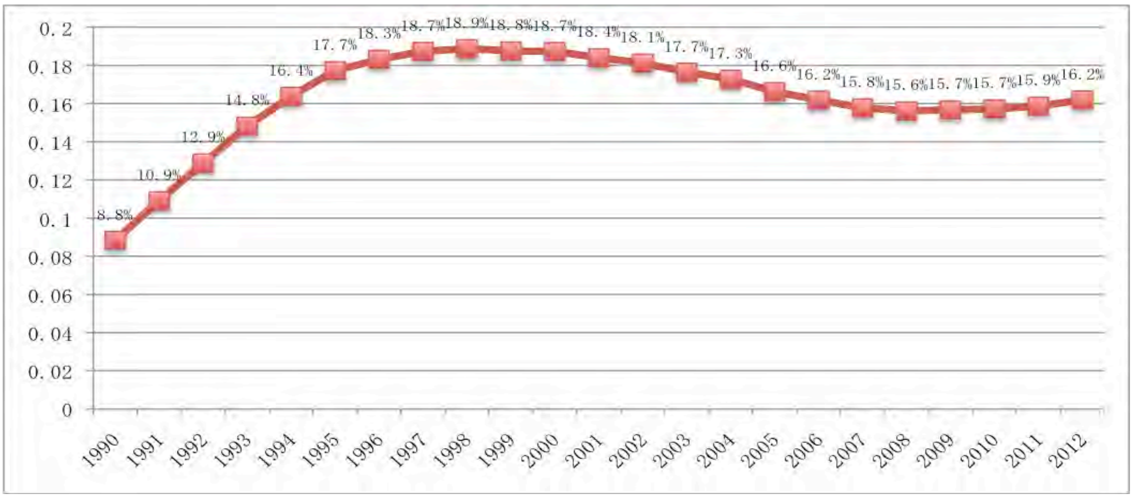
Table 3.6.1. Ratio of female engineers

	Total	Female	Ratio
Forestry and Fisheries Engineers	47,965	6,990	14.6%
Electrical Engineers	281,880	8,543	3.0%
Mechanical Engineers	204,394	6,139	3.0%
Transport Machinery Engineers	79,644	2,498	3.1%
Metal Engineers	16,375	330	2.0%
Chemical Engineers	66,994	7,136	10.7%
Architects	232,686	19,993	8.6%
Civil Engineers	306,797	6,640	2.2%
Systems Engineers	745,153	85,824	11.5%
Software Engineers	74,831	15,982	21.4%
Other Informations Engineers	21,830	661	3.0%
Other Engineers	62,063	4,706	7.6%
Total	2,140,612	165,392	7.7%

from National Census 2005,

http://www.e-stat.go.jp/SG1/estat/GL08020101.do?_toGL08020101_&tstatCode=000001007251

Figure 3.6.5. Ratio of female students in colleges of technology



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

3.7. Summary

An analysis of basic information regarding Japanese STEM education reveals the following critical issues: 1) Lack of enthusiasm for science and technology both among children and Japanese society as a whole; 2) Declining enrolment in STEM classes and courses at the senior secondary and undergraduate level; 3) Lack of teachers with in-depth knowledge of STEM subjects; 4) Lack of clearly established career paths for postdoctoral STEM researchers despite the expansion of graduate programs; 5) Low enrolment of female students in STEM courses and gender disparity in STEM careers. In the next chapter, the measures MEXT has created and implemented to address these issues will be examined.

4. Strategies, policies and programs to enhance STEM

While the Science and Technology Basic Law of 1995 delineates long-term national goals, the Council for Science and Technology Policy[7] established therein provides a mechanism to deliberate on mid-term strategies. These together form the overarching framework within which Japan's national STEM policies and priorities are embedded (see Section 2). Importantly, the restructuring of central government ministries, particularly the merger of the Ministry of Education, Science and Culture with the Science and Technology Agency, resulting in the establishment of the Ministry of Education, Culture, Sports and Science and Technology (MEXT) in 2001, allowed comprehensive promotion of science and technology through education. STEM education has since been advanced as a locus for effective coordination of multiple agendas aligned through administrative reorganization.

In reality, the restructuring was part of a larger effort to downsize government, and, accordingly, the national budget for public education has continuously been slashed over the past decade due to decentralization and increasingly neo-liberal inclination of government policies. The contribution of the national budget to the total cost of public education rests at 30%, with the remaining 70% shouldered by prefectural and city budgets (Sato 2011:227). Sato (2011) contends that many aspects of public education have in fact been significantly weakened due to 'the politics of reform' carried out over the past quarter of a century, particularly since the beginning of the new millennium.

The government's STEM strategies and programs thus inhabit a climate of austerity against a backdrop of mounting criticism and concern over deteriorating STEM performance of Japanese students as well as lack of enthusiasm for STEM subjects, as outlined in Section 3. Public outcry over poor results in international achievement tests, commonly referred to as 'PISA shock', and negative press exposing university students' degenerating skills in mathematics put pressure on the government to raise national STEM capacities (Okabe, Tose and Nishimura, 1999)[8]. At the same time, there has been a growing sense of alarm in both the government and corporate sectors over *rika banare*, or increasing apathy toward science among Japanese youth, which

7 The council takes initiative in setting the direction of national science and technology promotion policies implemented across ministries based on basic plans renewed every five years. See Kitazawa (2010:31-32).

8 For instance, a book entitled "Bunsū no Dekinai Daigakusei" [University Students Who Do Not Have Fraction Skills] created a public uproar regarding the deteriorating math skills of university students after the *yutori* relaxed education was introduced at primary and secondary schools.

poses a serious threat for future national sustainability.

This section will review several notable STEM strategies, policies and programs of late, particularly those conceived of and implemented over the past decade. As the promotion of STEM and STEM education have persistently constituted a national priority throughout Japan's modern history, the programs outlined here do fully not capture the depth and magnitude of overall national policies adopted to enhance STEM in Japan. Rather, they represent prioritized programs or the most significant recent moves with nationwide impacts. Some signify a pivotal turning point for STEM education policy, marking a departure from the old norm of egalitarianism to an emphasis on 'elite' training in public education, while others tackle emerging challenges related to international competition, globalization, and the declining population that will inevitably lead to a decrease in the number of STEM professionals.

In the following subsections, four key strategies are examined. The first is the enhancement of compulsory STEM education through a major revision to the national Curriculum Guidelines that resolves to increase the study hours and content in primary and secondary schools, as well as other programs aimed at improving science teaching. The goal of these initiatives is to improve the quality of basic STEM education nationwide, generating and stimulating interest in scientific topics, thus creating a broad support base for STEM in Japanese society. The second involves programs to nurture and train the best and brightest STEM talent by enhancing 'elite' education. This is showcased by the Super Science High School (SSH) program launched in 2002 along with subsequently established programs that lay the foundation for a 'science elite track' from secondary to tertiary levels of education. The third facilitates transitions between university and career paths by supporting job placement of graduate students and post-doctoral researchers who complete degrees in STEM fields. The fourth specifically addresses the underrepresentation of women in STEM education and careers and features initiatives supported through both public and corporate sector funding.

4.1. Education to create a solid science base in society: 'Science for all'[9]

In 2008, MEXT released a new set of national Curriculum Guidelines (*gakushū shidō yōryō*), which are implemented in phases at primary, secondary and high schools nationwide and contain provisions for review and reformulation every ten years. The new Curriculum Guidelines drastically increased classroom hours and course content of mathematics and science courses, marking a stark reversal of the so-called '*yutori kyōiku*' or 'relaxed education' policy set forth by the previous Curriculum Guidelines a decade prior.

[9] The terms 'Science for All' and 'Science for Excellence' are used in a 2005 report on governmental policy council meetings established for the enhancement of science and technology. See Tanaka (2006:57-83).

As discussed at Section 3, the new Curriculum Guidelines of 2008 increased the school hours of compulsory subjects almost to the standard held in 1989 (see Figure 3.4.1 and 3.4.2). The class hours of primary and secondary school mathematics and science classes were expanded by approximately 10%. The expansion of course content was relatively more conservative, which, according to MEXT, was targeted to place greater importance on observation, experiment, discussion and application of knowledge to real life situations. For primary and secondary school mathematics and science classes, the Curriculum Guidelines were revised with reference to international standards in science education and emphasized systematic introduction of study content. Study of computer and information science at primary through high school levels was also enhanced by adding content and making some classes compulsory while highlighting in particular the ethical protocol surrounding networking and information processing.

The revision of *yutori* education marks a pivotal moment for reexamination of Japanese education policy over the last decade. Japan's rapid economic growth in the latter half of the twentieth century was in large part achieved through technological progress and engineering, which were supported by the education system. The expansion of the manufacturing industry, for example, would not have been possible without the contribution of highly educated, industrious engineers, who were products of a demanding curriculum that required students to study harder for longer hours and imposed a harshly competitive university entrance examination process. Since the late 1970s, however, Japan had sought a new direction in which to move the national education system, transitioning from the post-war 'catch-up' mode to one that befitted a mature state with accomplished economic standing and advanced science and technology. Post-war emphasis on the acquisition of systematized knowledge of science and practical skills was in fact long considered inappropriate and outdated. Through the reforms instituted by the three consecutive national Curriculum Guidelines of 1977, 1988 and 1998, Japanese education policy has gradually shifted from a teacher-centered to a learner-centered paradigm, stressing literacy over mechanical memorization and bestowing importance on cultivating personal interest, motivation and attitudes (Oki 2011:132). Also, heavy reliance on entrance exam results and transmission-oriented instruction were criticized as the root from which stemmed various social problems (Bjork, 2011:148). 'Relaxed' or 'flexible' education policy was devised to 'reduce the pressures experienced by students and to augment their motivation to learn' as well as rectify the uniformity and rigidity of the education system which was considered to be preventing students from acquiring appropriate skills and knowledge (ibid.).[10]

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10 On the basis of the new notion of *yutori* or 'relaxed' education, the Curriculum Guidelines of 1977 reduced the number of school hours and curriculum content of mathematics and science classes (see Figure 3.4.1 and 3.4.2). The Curriculum Guidelines of 1989 continued in this vein, increasing the hours of elective subjects in hopes of spurring current trends in social and economic internationalization and the development of lifelong education practices. The impact of *yutori* education policy peaked at the time of publication of the 1998 Curriculum Guidelines. The 1998 Guidelines further reduced

Although national education policy (including *yutori* education) addresses all fields of learning, it is important to note that the reversal of *yutori* education derives primarily from concerns over deteriorating STEM capacity and quality of instruction. Triggered by reactions to PISA results from 2003, strategy to rectify the decline of both quality and quantity of science education ranked among the most important agendas of the new Guidelines, reflecting the increasing clout international comparison had garnered in public opinion and policy deliberation in Japan. MEXT argues that even with the new Guidelines, the principles and direction of education policy of the past decades remains unchanged. In the public eye, however, realignment of policy spanning this period has definitively shown that academic strength is achieved through increased contact hours and study content. Providing students with flexibility and 'room' to grow may have its merits, but the relaxed education measures fell short of achieving their goal of enhancing students' enthusiasm or interest. Many families and schools failed to take advantage of the flexibility afforded through relaxed education policy to promote creative and independent learning of children. Instead, children and young students filled spare hours playing computer games and exchanging text messages (Oki 2011:136-142).

The realignment of education policy over the past decades has altered Japanese education in a number of important ways. This point will be revisited in the remainder of this section. It has also resulted in improvement in aspects of the educational infrastructure, such as the student-teacher ratio. The student-teacher ratio in mathematics, for instance, was reduced from 131 in 1992 to 93 in 2010 for junior secondary schools, and 153 to 114 over the same period for senior secondary level schools (See Figure 4.1.1 for junior secondary schools and See Figure 4.1.2 for Senior Secondary Level).

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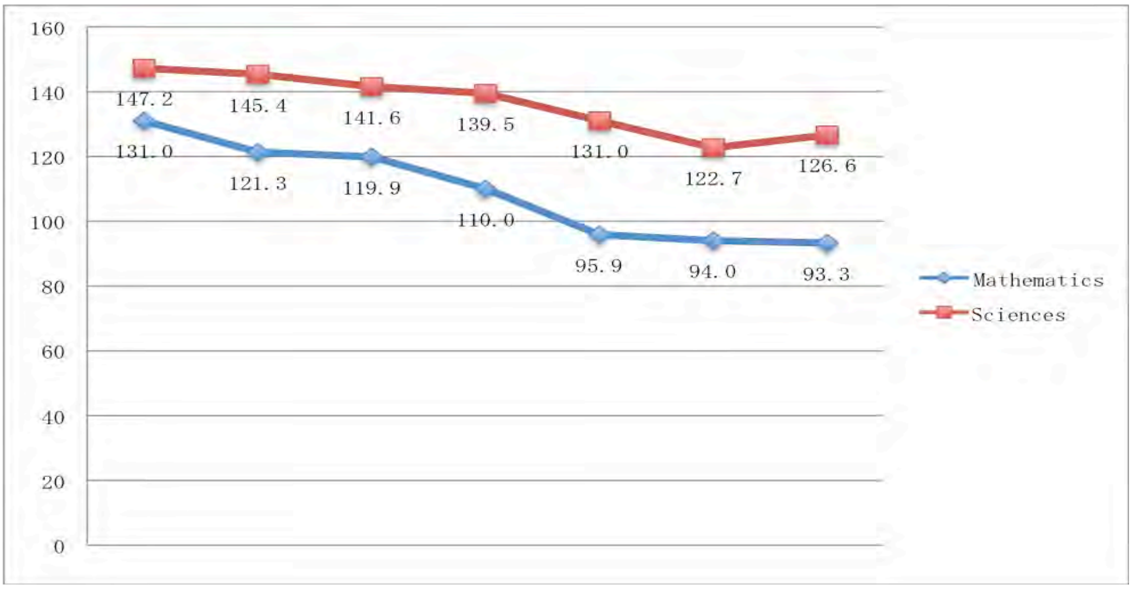
the number of school hours of mathematics and science classes from the levels stipulated in 1977: approximately 150 hours were allotted for mathematics in primary education, and 50-70 hours for junior secondary mathematics as well as primary and junior secondary science. The content of math and science curricula were also reduced by thirty percent and simplified.

Figure 4.1.1. Ratio of students/teachers in junior secondary education



from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/GL08020101.do?_toGL08020101_&tstatCode=000001016172&requestSender=dsearch

Figure 4.1.2. Ratio of students/teachers in senior secondary education

from Basic Survey on Education, http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015843&cycode=0

Moreover, the importance of providing students at the primary level opportunities to locate and observe science in daily life was acknowledged and put into practice. By following models of STEM education reform elsewhere, such as the ‘National Science Standards’ in the United States and the ‘Common Framework of Science Learning Outcomes’ in Canada, introducing basic science literacy training at the primary level prior to teaching advanced programs at the secondary level has become the norm (Ogura 2007).

Along with reform of the Curriculum Guidelines, training of primary school science teachers has become a priority in efforts to improve the nation's basic science education. In Japan, primary school teachers are responsible for instructing students in all subjects; however, the majority specialize in humanities or social sciences, as suggested by the type of secondary level teaching licenses they hold in concurrence with primary level teaching licenses (see Figure 3.4.3). As discussed at Section 3-4, only 6.6% of teachers have secondary level teaching licenses in science and 5.5% in mathematics, much less than those who have teaching licenses in Japanese (11.9%) or Social Science (16.9%). This indicates that the majority of primary school teachers did not acquire specialized knowledge of science in higher education either by majoring in STEM disciplines or by focusing on science in teacher's training courses. Such a circumstance not only affects the quality of science education but also weakens the linkage between science education and the forefront of science research and innovation.

Many of the programs implemented by the Japanese government to improve STEM education in schools and promote a broad base of general scientific understanding and interest in society are administered through the Japanese Science and Technology Agency (JST). JST has initiated a number of programs that can be categorized as broad-based or 'science for all' initiatives.[11] One of the most recent is the 'Establishing Training Centers for Core Science Teachers (CST)' program launched in 2009.[12] MEXT allocated a maximum of 35 million JPY per year for four years to be awarded to ten selected universities cooperating with local governments, for a total of 340 million JPY per year. Upon its inception in 2009, seven programs were selected and financed through the initiative. The following year five additional programs were selected, and in 2011 two more were added. Again in 2012, two universities were selected and provided with 20 million JPY each.

Establishing Training Centers for Core Science Teachers seeks to combat *rika banare*, or apathetic attitudes toward science among Japanese youth, by increasing the number of qualified STEM teachers who are confident and enthusiastically committed to teaching science subjects. Teacher-training and workshops designed to improve the quality of instruction of both aspiring and current STEM teachers[13] are jointly executed by prefectural and municipal

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11 STEM education is addressed as a facet of 'building infrastructure for creation of innovation', one of the three main pillars of JPS's mission. See JST website <http://www.jst.go.jp/EN/operations/operation2_b.html> for information about ongoing programs that promote broad-based science education at schools and in society. For a list of past programs and projects to enhance STEM education, refer to JST website <http://rikai.jst.go.jp/zoshin/about/about_past.php> (in Japanese).

12 For an overview of the Establishing Training Centers for CST program, see <http://rikai.jst.go.jp/eng/e_about/e_cst.php> (in English). This page includes a link to the program's Japanese website, which introduces all of the programs selected to receiving funding each year and includes a brief description of their main objectives (in Japanese).

13 Application Guideline of Establishing Training Centers for Core Science Teachers (in Japanese), from

boards of education in cooperation with science and/or education departments of partner universities. For example, Ochanomizu University and the Tokyo Board of Education conduct a 2-year program that offers graduate students in STEM fields the opportunity to acquire primary school teaching credentials while studying to obtain their graduate degree. Also participating in the program are current teachers who have been recommended by local school boards. CST programs are designed to strengthen teachers' ability to put into practice fundamental knowledge of STEM through classroom activities that illustrate basic principles in ways that captivate students' interest and nurture their curiosity. Upon successful completion of the program, participants receive certification of recognition as Core Science Teachers. As leaders in STEM education, they are expected to disseminate the knowledge they have acquired through the CST program in the form of lectures and regional workshops attended by primary school teachers, who often claim to lack confidence when it comes to teaching math and science subjects.

Furthermore, the strong tradition of senior teachers transmitting knowledge of best teaching practices to their junior counterparts is threatened by the fact that over the past decade 34% of the nation's teachers have retired, leaving a large portion of teaching positions open to candidates with little or no teaching experience. Thus, participants in CST training programs, who include graduate students obtaining degrees in STEM fields as well current teachers at primary and secondary schools with varied levels of classroom experience, greatly benefit from the opportunity to exchange ideas, advice and expertise with their colleagues.

4.2. Training of science elite through the reinforcement of cooperation between senior secondary and higher education

While the decline of students' academic achievement in basic science has been regarded as a serious issue, the government has launched a number of programs that specifically focus on cultivating talent or scientific 'elite'. Such programs are relatively recent in the Japanese public education sector, which had previously been based on stringent egalitarian rules and ideology (Kariya 2001). The majority of such elite training programs were launched in the early 2000s. Programs target different levels of education but generally aim to reinforce cooperation between senior secondary and higher education. Principal objectives of advanced programs at senior secondary and university undergraduate levels include cultivating and improving the ability to design and synthesize, leadership, communication, and problem-searching and problem-solving skills.

In 2002, MEXT launched the Super Science High schools (SSH) program targeting senior

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http://rikai.jst.go.jp/cst/file/h24/h24koubo.pdf secondary education.[14] 2.44 billion JPY per year for five years was allocated, with a total of 145 SSHs selected to receive funding in 2011. 71 schools were newly selected in 2012, and MEXT plans to increase the number of SSHs to 200 by 2014. SSHs develop and carry out special advanced curricula of mathematics or science, including collaborative study programs with universities or research institutions focusing on teaching logical and creative thinking through observations and experiments. Lectures and presentations in English are also held in order to strengthen international communication ability. In addition to innovative curricula, students in SSHs are encouraged to join extracurricular activities, often with but not limited to universities, such as International Mathematical Olympiad and International Physics Olympiad, where they are provided incentives for participation. For example, students demonstrating outstanding achievement may be given priority admission to universities, sometimes being exempt from regular entrance examinations.[15]

In short, the objectives of SSHs can be summarized in three main points: 1) creation of innovative curricula; 2) early introduction of advanced research through cooperation with universities; 3) enhancement of international abilities (Shigematsu and Yoko 2010:132-133). In addition, it remains important to provide high-level STEM education to students even as a part of compulsory education in order to increase the number of students who hope to go on to SSHs. SSH programs, highly concentrated on advanced mathematics and science subjects, are dedicated to the training of general literacy, based on the three literacies designated by PISA (mathematical literacy, science literacy and problem solving skills) (ibid.:135). Ogura (2007) showed that students enroled in courses at SSHs were on average more likely to have had been exposed to independent research activities during their primary school years than students enroled in regular high school courses (Ogura 2007:11-12). This finding confirms a correlation between the quality of science education in the early, compulsory years and participation in elite programs such as SSHs later on.

In the wake of successful programs aimed at cultivating a science elite track in senior secondary education, programs with similar focus are extended to undergraduate and postgraduate courses. In 2007, MEXT launched the 'Science and Mathematics Students Support Project',[16] renamed the 'Support for Development of Science and Mathematics Student Project' in

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14 https://ssh.jst.go.jp/

15 For example, Osaka University's Schools of Science, Engineering and Engineering Science announced new guidelines for admission of students with distinguished records at international science and mathematics Olympics beginning in April 2013. Not only are qualified applicants exempt from regular entrance exams, but upon the successful entry to the Schools their first year tuition fees are waved (continued waiver depends on academic performance in the first year). Students are also provided 'special support' to develop areas of individual excellence. Osaka University is a national comprehensive university, which is considered to offer some of the nation's best higher education in STEM disciplines and whose entrance exams are fairly competitive. http://www.osaka-u.ac.jp/ja/admissions/faculty/general/files/h25senbatsu_3.pdf, viewed 18 January 2013

16 http://www.mext.go.jp/a_menu/jinzai/koubo/06122815.htm

2011.[17] In 2012, MEXT allocated a maximum of 16 million JPY per year for four years to nine universities, for a total budget of 200 million JPY. The project provides financial support to universities that establish an honors program in undergraduate science and technology courses. In addition to the provision of advanced science education, the project emphasizes the cooperation between tertiary and senior secondary education. For example, as part of Kyoto University's 'Global Leadership Engineering Education Program', prospective students from regional high schools are invited to attend lectures delivered by world-renown STEM researchers addressing a class of nearly 1,000 incoming engineering freshman.[18]

Universities eligible for honors program funding provide education that enhances students' leadership, communication skills and collaborative spirit.[19] Programs are designed to stimulate competition among students and heighten their motivation through participation in academic contests, such as the Science Inter-College,[20] first held by MEXT in 2011. This follows in the steps of existing projects such as the 'Promotion of Public Understanding of Science and Technology'[21] launched in 2004 to support students' participation in various international contests and science and technology Olympics.

The science elite path is also evident in the establishment of highly-selective 'Leading Programs in Doctoral Education'.[22] In 2011, 21 programs in the nation's top 13 universities were selected to receive funding, followed by 24 programs in 17 universities selected in 2012. Leading Programs in Doctoral Education are created to offer integrated master's and doctoral programs that ensure a level of quality recognizable worldwide. According to the Japan Society for the Promotion of Science (JSPS), Leading Programs are interdisciplinary in nature with curricula that span a broad scope of fields of specialization and are 'underpinned by internationally excellent education and research resources and designed with participation of experts from not only academia but also the industrial and governmental sectors'.[23]
Each new Leading Program is eligible to receive a maximum of 300 million yen for the first year for up to seven years, with a total government budget of 3.9 billion yen in 2011 and 11.6 billion yen in the first year. Although the funding covers all disciplines and fields rather than STEM, about 80% of the projects (36 out of 45) are in STEM fields.[24]

4.3. Expanding postgraduate STEM participation through better job placement of graduates

17 http://www.mext.go.jp/b_menu/boshu/detail/1321489.htm
18 http://www.t.kyoto-u.ac.jp/en/education/programs/gl?set_language=en
19 For example, Osaka University Science Honors Program, http://www.sci.osaka-u.ac.jp/honors/
20 http://www.science-i.jp/
21 http://contest.jst.go.jp/shien/index.html
22 http://www.jsps.go.jp/j-hakasekatei/index.html
23 JSPS 2011-2012 brochure, downloaded from http://www.jsps.go.jp/english/aboutus/data/brochure11-12.pdf
24 http://www.jsps.go.jp/j-hakasekatei/shinsa_kekka.html

with doctoral degrees

As mentioned in the previous section, the policy of expanding graduate schools and increasing the number of graduates with doctoral degrees originating in the early 1990s created a gap in the labor market. Although the policy was devised to enhance Japan's international competitiveness vis-à-vis strategies adopted by other developed nations that produce large proportions of highly qualified labor in science and technology, employment opportunities for doctoral graduates have not increased to the extent and at the pace of nationwide expansion of postgraduate programs.

As the current plight of unemployed post-docs is in a way a product of MEXT's policy over the past decade, the government has undertaken carefully studies on the conditions of job placement among doctoral degree holders, particularly those in science and technology fields. This information is used to draft measures aimed at resolving the mismatch between the qualification and capacity of doctoral graduates that universities produce and human resources that industries seek, diversifying career paths of graduates, and promoting university-industry collaboration (Misu, Horoiwa & Chayama 2010:i).

The following will examine policies that facilitate transition of postdoctoral researchers from temporary positions to permanent research posts and attempt to bridge the existing gap between universities and the private sector labor market. The nature of policies implemented thus far tends to focus on support and assistance for graduates and thus fails to address the structural imbalance of the entrance-exit mismatch. A number of mitigating factors must also be considered. For one, linkage between university and labor market is not solely defined by education policy but affected by a number of factors outside the realms of academia and education policy-making, such as global economy, market and employment trends. In addition, tertiary education is more autonomous compared to primary or secondary level compulsory education, and therefore enforcement of government-led changes in curricula and programs can be problematic.

Among STEM departments and schools of top-tiered universities, strong inclination toward academic positions and careers continues to be the norm among both faculty and students, except in some engineering fields. This has been changing, however, as industry-university collaboration becomes commonplace and in particular following the corporatization of national universities in the early 2000s. The procurement of human capital for research and development (R&D) is also a major concern for industry considering long-term sustainability in an era of declining population. In Japan, R&D funds from the private sector have exceeded those from public sector and account for approximately 70% of the total national R&D expenditure, the highest ratio among developed countries.

One of the policies to support career development of young science and technology researchers is a five-year grant for universities and research institutions titled 'Improvement of Research Environment for Young Scholars', started by JST in 2006. The program allocates up to 200 million yen per year to 9-12 universities and institutions.[25] In 2012, total budgets for this program increased to 7.5 billion JPY per year. Selected institutions install a 'tenure track system' in which up-and-coming researchers are given fixed-term employment while they gain experience conducting independent research. Upon passing a strict evaluation at the end of the contract period, these young researchers are given tenure positions[26]. Although the program is not restricted to STEM fields, it is designated at host institutions as 'research organizations currently striving to become world-class research bases', effectively singling out most universities and institutions with strength in science and technology fields. The program also showcases a strong elite training element as with the programs mentioned in Part 2 of this section.

MEXT also promotes doctoral graduates' placement in the private sector by matching needs of companies and doctoral students through long-term internships. In 2006, JST launched the 'Young Researchers Training Program for Promoting Innovation', which allocates a maximum of 70 million JPY per year for five years to 6-10 universities or institutions, for a total budget of 2 billion JPY in 2012.[27]

Japanese companies are often reluctant to employ doctoral graduates, instead opting to hire master's students (see Figure 4.3.1). Only 2.4% of companies regularly employ doctoral graduates and 10.9% sometimes do, compared with 56.0% and 28.2% respectively for master's graduates. When they do hire those with doctoral degrees, however, they report higher satisfaction rates with their performances (see Figure 4.3.2). Thus the 'Young Researchers Training Program for Promoting Innovation' promotes internships for doctoral course students and postdoctoral fellows in private sectors in order to establish a variety of career-path opportunities. The program nurtures highly skilled professionals who are capable of undertaking innovative projects and who can work competitively for Japanese industry in a globalized context. A chief goal of the program is to achieve full uptake of STEM doctoral graduates into the labor market.[28]

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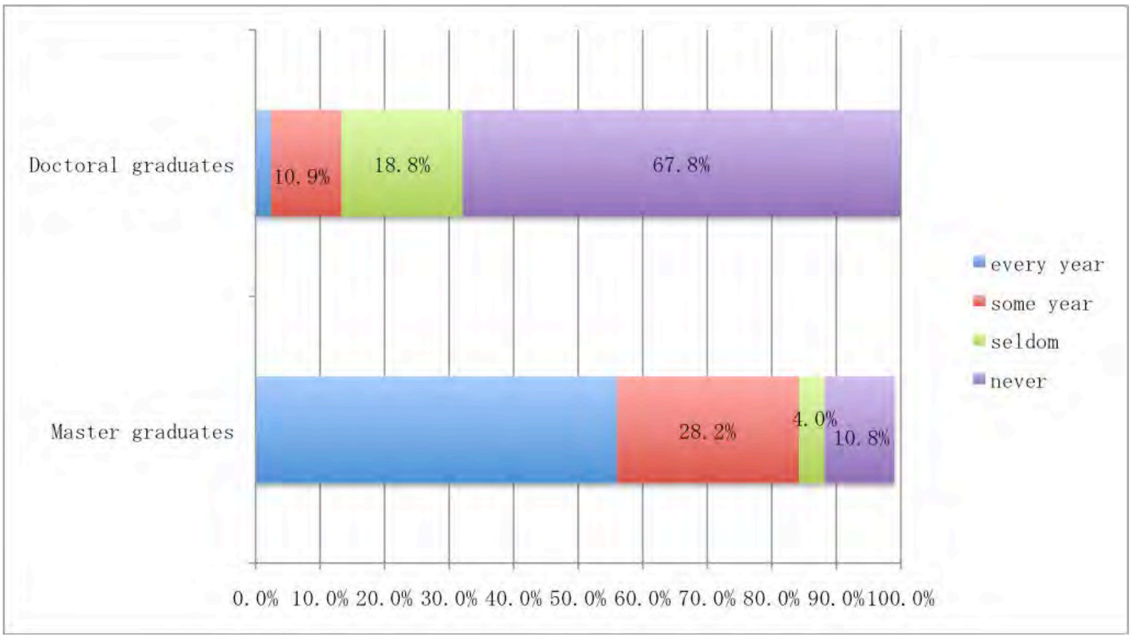
25 http://www.jst.go.jp/shincho/program/wakate.html

26 See JST website for details of the program. http://www.jst.go.jp/shincho/en/program/wakate.html

27 http://www.jst.go.jp/phd-career/

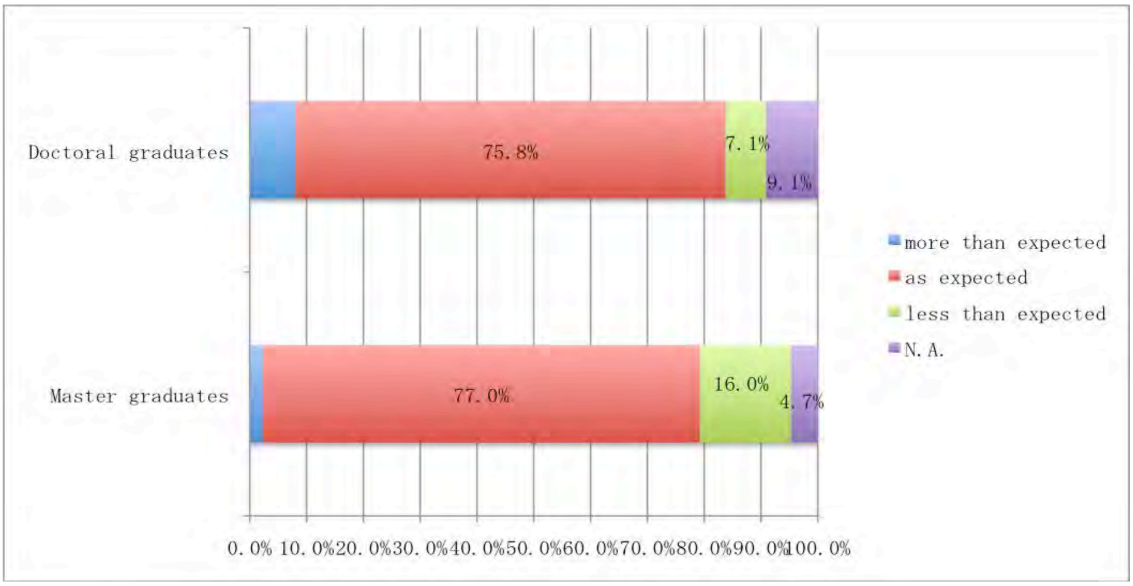
28 http://www.mext.go.jp/component/b_menu/other/__icsFiles/afieldfile/2012/01/10/1314895_8.pdf

Figure 4.3.1. "Private companies employ master's and doctoral graduates" (2007)



from NISTEP (2011b), http://data.nistep.go.jp/dspace/bitstream/11035/1174/3/NISTEP-NR152-FullJ.pdf

Figure 4.3.2. "Private companies are satisfied with master's and doctoral graduates" (2007)



from NISTEP (2011b), http://data.nistep.go.jp/dspace/bitstream/11035/1174/3/NISTEP-NR152-FullJ.pdf

Some of the recently established education programs at the tertiary level maintain an emphasis on collaboration with industry with the goal of producing skilled human resources capable of innovation. For example, Leading Programs in Doctoral Education, mentioned earlier, invites company researchers and managers to participate as lecturers, not only for the promotion of joint research but also for the placement of doctoral graduates. In light of decreasing enrolment in doctoral programs in science and engineering fields, Leading Programs in Doctoral Education provides incentives such as innovative education programs and scholarship opportunities for highly qualified prospective students.

4.4. Encouraging female participation in STEM study and careers

In June 2012, as part of its plan to 'promote the participation of women and vitalize the economy' (National Policy Unit, Cabinet Secretariat 2012), the Japanese government announced the goal of increasing the proportion of *rikei josei* or women in STEM studies and research. The current figure for women's representation in STEM studies and research, about 10%, is less than half that of most Western advanced economies. Increased share of women in science is furthermore considered to contribute to achievement of the overall national goal of increasing the share of women in leadership positions to 30% by 2020.[29] For STEM fields, the 4th Science and Technology Basic Plan, effective FY 2011, regards the active involvement of women researchers as a crucial agenda and sets a target of women constituting at least 25%, preferably 30%, of total researchers in overall natural science (STEM) fields. The Plan also designates more specific targets of 20% women's representation in science, 15% in engineering, 30% in agriculture, and 30% in public health.[30] Policy that enhances the participation of women in science is thus pursued as a means to achieve gender equality in society as well as secure human capital for science and technology, and by extension, sustainable economic growth as the working age population is expected to shrink due to aging (see Section 2.2).

With regard to female participation in STEM, two brands of policies have been implemented by the government. One provides childcare and other support to women who already hold research jobs and positions, and the other encourages more women to study STEM subjects and aspire to careers in STEM in order train the next generation of female researchers. More recently, there is a growing social movement to encourage girls and women, referred to as *rikejo*[31] or 'STEM girls', to participate in science and pursue scientific careers. Although *rikejo* remain a minority in schools and society, the attention they have received in a way improves the popular image of girls in science as 'cool' rather than 'geeks in the lab'. Activities to encourage and support *rikejo* have been launched by companies that wish to train and recruit them as part of corporate social responsibility programs, and information sharing and career counseling from women in STEM jobs have become more readily available to students. Although the *rikejo* boom is more a bottom-up initiative than a policy strategy per se, a brief introduction will be given in the following after a short summary of two major relevant policies.

[29] Gender Equality Bureau, Cabinet Office, the Government of Japan http://www.gender.go.jp/english_contents/mge/process/index.html

[30] Basic Plan for Science and Technology, 19 August 2012 (in Japanese), from http://www.mext.go.jp/component/a_menu/science/detail/__icsFiles/afieldfile/2011/08/19/1293746_02.pdf

[31] 'Rikejo' is a recently coined term, which is a shortened form of 'rikei joshi' or girls in broad STEM fields of study and work. The expression is increasingly popular as it appears in the media and generally conveys a positive image of smart and challenging girls.

The Japan Science and Technology Agency (JST) started a program in 2006 to support female researchers, though not specifically with a STEM focus, by encouraging institutions to take measures to improve work environments, allowing female researchers to continue working even while having and raising children.[32] Selected institutions are expected to create a support system by strengthening child-care facilities and improving job placement for women and also to provide models for other education and research institutions throughout the country. The program operated on an annual budget of 730 million yen in 2012 and allocates a maximum 20 million JPY per year for 3 years to about 10 universities, colleges of technology and other institutions.

With the goal of training the next generation of female STEM researchers and technical personnel, MEXT launched a program, also in 2006 (the same year the above-mentioned female researchers program was established), to encourage female junior secondary and senior secondary students to enrol in science courses.[33] Through activities such as experiments and lectures organized by host institutions, female students are given opportunities to interact with female researchers and engineers. Positive encounters with 'role models' are considered to give them better ideas about their options and possibilities for further studies and careers in STEM after graduation. Some host institutions maintain websites to provide information about science courses at universities and work opportunities, while others invite parents and school teachers, whose opinions are considered to be important to girls making decisions about education and work, to participate in science-related activities along with students.

In addition to government programs implemented through schools and universities, there are a growing number of bottom-up *rikejo* activities initiated by corporations. '*Rikejo* boom' is said to have struck in 2011 when it was widely reported in the media that a chemistry paper written by female students at Mito Dai-ni Senior High School was published in an international refereed journal, The Journal of Physical Chemistry. It is rather unusual for high school students to contribute an academic paper to an international refereed journal to begin with, and the fact that young girls received international recognition through their contribution to science played into the construction of a 'girls can do science' image. Several of the authors were members of a science club at a public high school, incidentally one designated as Super Science High School (SSH, see Section 4.2).

Concurrent with the *rikejo* boom, Kodansha, one of the major publishing companies in Japan, operates a '*rikejo* project' to encourage girls who aspire to pursue STEM studies and careers by

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32 See JSP website, "Supporting Activities for Female Researchers": http://www.jst.go.jp/shincho/en/program/woman_ken.html

33 http://rikai.jst.go.jp/eng/jyoshi/index.php

providing information to registered members concerning jobs, universities and counseling services through their *rikejo* website, publishing a free *Rikejo* magazine, organizing science events for girls, as well as other activities[34] They mobilize women who occupy research and technology positions in companies by encouraging them to register as ‘mentors’. Electronic companies such as IBM Japan and Panasonic as well as major domestic and international cosmetics brands such as Shiseido and L’Oreal Japan are reported to sponsor science events and lectures for female students, provide grants for female science researchers and awards to female scientists as well as doctoral students (Nihon Keizai Shimbun 12, August 21). Whether or not the boom will be sustained and continue to develop remains largely to be seen. There are some signs of progress, however. According to a report by a local edition of Asahi Shimbun newspaper,[35] for instance, the number of girls who graduate from senior secondary schools in Saitama prefecture who enter faculties of science, engineering, agriculture and health in higher education increased by 50% between 2002 and 2011. The report cites activities carried out by schools and companies to encourage girls to study STEM subjects and the popularity of health related jobs such as doctors, pharmacists, and nurses as factors contributing to the marked increase. The report also mentions that for the boom to be successful over a longer period of time, the general work environment for women needs to be improved.

5. Discussion of STEM policies and programs in Japan

5.1. Lack of comprehensive, STEM-specific national policy

Japan has no comprehensive national STEM policy. As such, STEM learning and human resources development are promoted as part of overall national policies concerning science and technology as well as education and human capital development, both of which are largely, though not exclusively, pursued under the aegis of the MEXT. Despite close cooperation between ministries overseeing education and science and technology within the central government administration, as noted at the beginning of Section 4, there is no coordinative practice for monitoring and evaluating the progress of various national policies in their capacity to affect conditions of STEM specifically. The practice of incorporating STEM into policies and programs without giving it primary focus results in fragmentation of information, making it difficult to synthesize a cohesive picture of national STEM strategies and programs, their impact and shortfalls. Doing so requires not only an understanding of current status and statistics, but also of shifting policy priorities and adjustments, as well as changing needs and demands towards STEM spanning wide sectors of society.

[34] According to the Kodansha Rikejo website (http://www.rikejo.jp/stc/campaign/), at the time of the *Rikejo* magazine’s first anniversary in fall 2011, they had close to 10,000 registered members.

[35] ‘Fueru rikejo motto mae e [Growing number of rikejo: Moving ahead]’ The Asahi shimbun digital, 2012, February 11, downloaded from http://mytown.asahi.com/saitama/news.php?k_id=11000691202130001

One important omission to the analysis of STEM policies in Japan presented in the previous chapters is the identification of international students as a prioritized area of Japan's STEM strategies and development. In 2008, then Prime Minister Yasuo Fukuda announced a plan to send 300,000 Japanese students abroad and accept 300,000 international students to Japanese universities by year 2020, known as the '300,000 International Students Plan' (*Ryūgakusei Sanjūman-nin Keikaku*), the framework of which was outlined by MEXT, in cooperation with several other government ministries and agencies. The Plan was launched on the understanding that 'high-quality foreign students can contribute to the research agenda of host universities and help increase the overall competitiveness of Japanese universities in this era of globalization' (Ninomiya, Knight & Watanabe 2009). This clearly marked a departure from the previous, aid-oriented '100,000 International Students Plan' formulated in the 1980s (Ishikawa 2011). While the plan neglects to define STEM area targets specifically, stating that 'efforts should be made to strategically acquire excellent international students…while giving due consideration to the balance of countries, regions and fields of study' (MEXT 2008a:3), deliberations leading to the Plan's establishment and subsequent implementation include explicit reference to STEM in terms of strategic recruitment objectives for Asia. For example, the importance of recruiting Asian students to Japanese graduate schools in areas such as physics, chemistry, engineering, life sciences, information, public health and medicine, agriculture, and environment studies (MEXT 2008b) is stressed along with monitoring the status of international student enrolments in science and technology fields in other host countries.[36]

The fact that the 300,000 International Students Plan constitutes a joint endeavor by six ministries rather than a policy under the sole jurisdiction of MEXT demonstrates that the issue of international students is set within a broader context that incorporates the nation's economy, human capital development, immigration, and labor. Business communities clearly see merit in employing international graduates in technical fields (scientific research and development) and thus support the 300,000 Plan as well as the subsequent 'Global 30' initiative.[37] Such government programs, however, are pursued with the overall goal of increasing the number of international students by enhancing the competitiveness and attractiveness of Japanese higher

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36 The percent of international students at Japanese institutions of higher education is relatively low (3.3%) when compared to the US (5.5%), UK (25.1%), Germany (12.4%), France (11.8%) and Australia (26.2%) (MEXT 2008b:7). Approximately half of the international students studying in Japan as of May 2007 were enroled as undergraduates, and just over one quarter were enroled in graduate school. Of that one quarter, 21.3% belonged to STEM related faculties, namely science, engineering, agriculture and medicine, dentistry and pharmacology (MEXT 2008b:11-13).

37 The Japan Business Federation (*Keidanren*) published a report in 2009 calling for the enhancement of both the 'quality and quantity' of international students in technical fields (in Japanese): http://www.keidanren.or.jp/japanese/policy/2009/014.pdf, viewed 28 January 2013.

education and do not clearly demarcate strategies nor set specific goals for STEM areas. Consequently, the ability to duly analyze the impact of an increased number of international students on Japan's STEM development and enhancement is compromised, with evidence being scarce, at best.[38]

The lack of STEM focus and priority in Japan's innovation policies may also mask other emerging, worrisome trends. Data presented thus far in the report include policies and programs concerning health and life sciences, as there is no equivalent term for 'STEM' in Japanese (See Section 1.3). Considering the fact that life and health sciences are not only robustly supported areas of research but also continue to provide expanding employment opportunities, a larger, more inclusive STEM picture that incorporates these STEM-related fields may belie the diminishing interest and career opportunities in 'narrower' STEM fields. Furthermore, health and life sciences, particularly nursing and public health, define areas of research and jobs characterized by the high and growing participation of women. In order to adequately capture and effectively address phenomena such as the underrepresentation of women in science and shrinking numbers of doctoral students in STEM,[39] the creation of targeted programs and an analysis exclusively focused on narrower STEM fields may be warranted.

If not STEM-specific policy, Kobayashi (2011) calls for comprehensive national discussions concerning the training and retention of human resources for innovation, referring to recent policy initiatives of many foreign governments. In Kobayashi's view, Japan needs not only to adapt to the globalization of innovation but also employ a globally competitive approach to enhance human resources for innovation (ibid.).

5.2. Science advocacy to inspire children and youths remains a challenge

Many science and mathematics education experts in Japan single out the low aspiration of children to take up STEM subjects and pursue STEM careers as posing the most difficult challenge for national STEM promotion and enhancement. As early as 1993, the *White Paper on Science and Technology*, published annually by the former Science and Technology Agency, identified an alarming trend in which Japanese youths displayed increasingly apathetic attitudes toward science. A series of government policies intended to reverse the trend and

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38 There is some evidence, such as an increase in international science and technology faculties composed primarily of Asian researchers who graduated from Japanese universities (Ishikawa 2011:212).

39 Japan's most promising students in STEM do not go on to doctoral programs in natural science fields and thus do not fully utilize the mathematics or physics they have studied in high school, according to Enoki (2010:14-15). Drawing on his personal experience of leaving a doctoral program at the Graduate School of Science of the University of Tokyo to major in medicine at another national university, Enoki argues that Japan's most promising science talent all too often forgoes studies in basic science to pursue careers in medicine, citing the fact that seventy out of the top 100 students taking the National Center Test for University Admissions (*Daigaku Nyūshi Sentā Shiken*) choose to enter a faculty of medicine (15).

promote STEM among youths and the general public have been implemented since, the most recent of which are outlined in Section 4. The same *White Paper* also points out, however, that such apathetic attitudes are not particular to Japan, but rather are shared among the populations of many developed countries such as the United States, United Kingdom, Canada and Italy, all of which are presumably in transition to a post-industrial society.

Reviewing post-war policies implemented up until the early 2000s aimed at enhancing Japanese citizens' science and technology literacy, and looking in particular at those policies appearing since the 1990s that specifically address the apathy issue, Tanaka (2006:80-81), a MEXT official and an expert on Japan's science and technology policy, concludes that many measures designed to improve STEM literacy 'for all' have in fact been effective only as 'for excellent' or elite programs. Tanaka analyzes policy development and compares measures taken by the Japanese government with those taken by countries overseas, finally concluding that too much emphasis on achievement-based evaluation of national science and technology policies can prove detrimental to the task of broadening the science base within society. Instead, shifting emphasis from 'understanding' to the creation of 'empathy' and 'trust', a new development in some Western countries, may offer a way for Japan to cultivate broader support for STEM in national science and technology development (Tanaka 2006:83).

On the other hand, Masuda (2007:24-25) notes that growing awareness on the part of the government and Japanese society of the need to rectify *rika banare* or increasing apathy toward science, which led to the implementation of government strategies since the late 2000s aimed at doing so, have made significant progress in increasing the number of children who claim to like science as well as improving the science literacy of Japanese citizens. He cites examples of recent government policies (such as those outlined in Section 4) and various initiatives undertaken by universities, corporations, museums, and non-profit organizations to organize science lectures, science cafés and other events for children and the general public, concluding that such activities for science advocacy have rendered promising results.

What remains to be done, Masuda argues (2007:25), is to elevate the social status and 'rewards' for STEM workers. There is a prevalent belief in Japanese society that science and technology researchers and engineers are paid less and promoted less quickly, and hence their lifetime incomes are not comparable with humanities and social science graduates in managerial positions (Mainichi Shinbun Kagaku Kankyo-bu 2003).[40] It is therefore not

[40] According to a study entitled Rikei Hakusho, which roughly translates as "STEM whitepaper", there is substantial evidence and data to confirm this perception. Japanese STEM workers are paid less and promoted at slower rates than their humanities and social science counterparts. In addition, top positions in the government and major corporations as well as the national Diet are predominantly occupied by non-STEM graduates. Recent and notable exceptions are the two former Prime Ministers belonging to the Democratic Party of Japan, Yukio Hatoyama, Ph.D. in engineering from Stanford University and Naoto Kan, who received a bachelor of science from Tokyo University of Technology. Their short-lived premiership did not contribute much to change the commonly-held view on leaders with science and engineering backgrounds, however.

surprising that young people do not have STEM aspirations even if they like to study science and math in school. To transform such a negative image, multiple intervention programs at the state rather than institutional level are necessary (Masuda 2007:25). Masuda also stresses the importance for scientists and engineers themselves to be more engaged with society and communicate the value and meaning of their work and, by extension, the promise science and technology hold for the future (ibid.).

Amid industrial restructuring that shifts the focus away from manufacturing to other sectors such as finance and information science, it has proven difficult to arouse enthusiasm for STEM research and technical careers among Japanese youth. However, if the recent *rikejo* or STEM girls boom is indicative of anything, it shows that outstanding achievements of one's peers can motivate students and inspire younger children to study science. As far as 'science for excellent' strategies in Japan are successful, as Kobayashi argues, they may generate new interest and possibly contribute to broadening the support base for STEM in society. 'Science for all' and 'science for excellent' thus may not necessarily constitute distinct approaches to enhancing STEM. Rather, the two may be fused, much in the way the international success of SSH-trained girls inspired countless others to pursue STEM careers.

5.3. Educational foundation and policy oscillation

Reviewing education policies and reforms in Japan, both past and present, Schleicher (OECD 2012b:192) identifies Japan's strength as having 'clear and ambitious academic standards across the board' by providing 'a strong and coherent delivery chain through which curricular goals translate into instructional systems and practices, and student learning'. The National Curriculum Guidelines, which are revised every ten years and any changes to which are subject to intense national scrutiny, dissected in the media, and given ample attention by teachers, parents and other stakeholders, serve as case in point. Adjustments and changes to the Curriculum Guidelines are accordingly implemented nationwide. Delivery of quality assurance through core national curricula guarantees a high standard of education and equity for those who participate in public education from primary to secondary levels. A competitive pay scale, high social regard for teaching professions, system of training and retraining, common practice of 'lesson study' (in which teachers conduct model classes and share best teaching practices) (OECD 2012b:195-197), and rotation of public school teachers to new schools every few years ensures the quality of teachers is also high, although Sato (2011)[41] notes that teachers in Japanese public schools are increasingly exposed to greater workloads and pressure.

Needless to say, the general portrayal of education in Japan applies to STEM as well.

[41] Schleicher also warns against Japan's having prioritized the reduction of class size too much, thus depleting public investment from other more important areas for ensuring the quality of teaching (OECD 2012b:197-198).

In fact, many of the wide scope educational reforms affecting STEM were influenced by an upheaval of the traditional, transmission-oriented model of teaching and learning in favor of new pedagogical approaches that incorporated insights from a growing body of research on the effectiveness of creating learning environments (Vande de Berg, Connor-Linton and Paige 2009) in which students acquired critical thinking and problem solving skills rather than rote knowledge. This resulted in a fundamental qualitative change in Japanese teaching methods. The image of Japanese primary and junior secondary schools as 'quiet, intense places where students copy down everything the teacher says' is no longer a reality (OECD 2012b:194). Rather, teachers aim to involve students in deeper understanding, with comparatively less drilling or lecturing time, and emphasize problem solving through cooperative work and mutual learning (ibid.). Schleicher, for instance, a PISA and education policy expert, provides the example of science classes in Japan that use lab experiments to explore problem-solving strategies (ibid.).[42]

Such a paradigmatic change was in fact lauded as one of the major objectives of so-called relaxed or *yutori* education, and in the very least was aligned with the thinking behind the *yutori* initiative (see Section 4.1). In public discussions leading to the latest revision of the Guidelines, however, much of the blame for Japanese students' poor performance on PISA 2003 was directed at the relaxed education policy, when in fact these scores were based on the performance of students who had only undergone two years of *yutori* education out of nine years compulsory education total. On the other hand, slightly improved performance on PISA 2009, while consistent with the aims of special programs designed at improving PISA literacy implemented since 2005, reflected the performance of students who had undergone eight years of *yutori* education (see Matsushita 2010 and Section 3.1 for discussion). Those who opposed *yutori* education from the beginning therefore capitalized on 'PISA shock' to further their agenda.

Japan's strength of a solid educational foundation is also a product of regular policy analysis and adjustments to the existing system occurring through referral to international comparative indicators and bench-markings. Revisions of the Guidelines form part of these alignment efforts to improve the quality of education throughout the nation. However, policy discussions based on unfounded evidence and changes initiated by 'politics of reform' (Sato 2011) are not conducive to sustainability and long-term planning for human capital development.

The 1998 Guidelines, or *yutori* policy, which reduced contact hours as well as study content, were unpopular particularly at the secondary level because they were not aligned with the priorities of schools or with those of students' parents (Bjork 2011:165). Education at the

[42] Also, see TIMSS Video Study 1999 of mathematics and science lessons in Japan as compared with other countries: http://timssvideo.com/timss-video-study. See lesson study examples.

secondary level is still very much defined by the system of university entrance examinations, which have remained competitive for top-tiered institutions. It is argued that emphasis on creative thinking and problem solving, considered to lie at the crux of education that fosters innovation, cannot be ensured unless college entrance exams reduce their focus on testing knowledge gained through transmission-oriented teaching and learning practices.[43]

University entrance exams also have a significant impact on secondary-level STEM enrolments. The stark decline in enrolment in physics courses in high schools (see Section 3.3) is as much the result of changes to curriculum requirements as it is of lax admission requirements set by some universities, who struggle to fill admissions as the 18-year old population continues to decrease. University admissions practices and entrance exams were the subject of recent national debates following a press conference in which President Hamada of University of Tokyo announced it would change the school year from April to fall in keeping with most universities worldwide and in order to remain 'internationally competitive' (Brasor 2012). Following his clarion call, some university leaders voiced the need for admissions reform, claiming the real issue is not 'when' school starts but rather 'how' the entrance exam is administered. Ongoing national discussions have fallen short, however, of provoking serious discussion of national strategies or programs that focus on the implications for STEM under the current the university entrance examination system.

Kaoru Takeuchi, a prominent and prolific science writer, warns in a recent interview of the precarious situation resulting from a drastic reduction in the number of students who study physics (Nakanome 2012). He points out that less than 30% of high school students today study physics, compared to more than 80% during the late 1970s to early 1980s, which will inevitably lead to decreased numbers of aspiring engineers and scientists. Although physics constitutes an area of research in which Japan has traditionally produced world-renown scholars, including eight Nobel Laureates since 1949, Takeuchi predicts that Japan may no longer excel in this discipline due to a thinning base at the secondary level. This issue, in contrast to *rikabanare* or science apathy, is not a matter concerning aspiration or lack of interest but rather secondary curricula and tertiary admissions, and it has yet to receive due policy intervention.

5.4. STEM for the future

As Japan strives to remain a world leader in technological innovation, it is compelled to seek

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43 There are signs that achievement tests at the secondary level are moving in that direction. For example, since 1997 MEXT has conducted an annual nationwide survey to ascertain the achievement of 6th year primary and 3rd year junior secondary school students in two subjects, Japanese and Mathematics, with Science added in 2012. The survey offers two basic types of questions, those testing fundamental knowledge and those targeting problem-solving skills by requiring students to provide evidence for how they reached the solution. (http://www.mext.go.jp/a_menu/shotou/gakuryoku-chousa/zenkoku/07032809.htm).

new models for the creation of highly skilled, globally competitive human resources while preserving the rigor of education and high standard of science and technology that have fueled its economic vitality and industrial progress for the last half of the former and first part of the 21st century. This challenge, however, looms increasingly formidable within the confines of strict, nationwide enforcement of study course content and educational methodology promulgated by MEXT. While entrusting supervision of material in a broad sense and fiscal conditions surrounding science education to a central government authority, as Nagahama (2009:183) argues, innovation may be fostered through increased autonomy of local stakeholders, allowing them to flexibly adapt to the rapidly changing nature of global society.

As discussed previously, Japan's STEM education has been deemed of limited consequence for broader society and has thus remained 'STEM for STEM people' (cf. Ogura 2007:7). The bitter experience of Fukushima, however, has taught the nation that science literacy is not only demanded of a cloistered elite but must be common among all people. Contentious energy policies need to be examined and debated, not only by specialists who report the latest scientific findings, but also by the nation's citizens, who share in the costs and burdens. After all, it is civil society that bears the responsibility for decisions that shape the future well-being of its offspring.

By empowering citizens with scientific literacy and carving out unique opportunities for the development of recognized talent, Japan as a nation prepares to meet the challenges of the new age. The resilience displayed in the face of recent crises speaks to the promise for a future in which long-term planning, political commitment and dedication to the goals of sustainability are expertly balanced with the drive to innovate, evolve and remain globally relevant.

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Abbreviation

・CST: Establishing Training Centers for Core Science Teachers
・CRET: Center for Research on Education Testing
・JSPS: Japan Society for the Promotion of Science
・JST: Japan Science and Technology Agency
・NIER: National Institute for Education Policy Research
・NISTEP: National Institute of Science and Technology Policy
・MEXT: Ministry of Education, Culture, Sport, Science and Technology, Japan
・SSH: Super Science High Schools
・WIPO: World Intellectual Property Organization