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Gender Segregation on Campuses: A Cross-Time Comparison of the Academic Pipeline in Japan, South Korea, and Taiwan

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ABSTRACT
Women's participation in science has been a major concern among Western feminists since the 1970s. Numerous European countries have collaborated to publish *She Figures* once every three years, which collects and compares the basic education and employment statistics for women in science and technology. However, such cross-country comparison is still rare in Asia. In this research, we collected statistics on the composition of students and faculty members in higher education in Japan, South Korea, and Taiwan from 2004 to 2014. Then we compared the patterns of gender segregation between European Union (EU) and the East Asia (EA) regions, followed by the comparison among the three EA countries. We documented that gender participation in science in the three EA countries has basically followed the patterns of the EU nations in terms of decreasing vertical segregation and stabilizing horizontal segregation. However the degree of segregation in EA is higher than that in EU-28, particularly in Engineering. Among the three EA countries, moreover, it is evident that South Korea has made better progress than the other two in the past decade in terms of women's participation in science, particularly at the Master's Degree level. Yet the increase of women's participation does not necessarily eliminate gender segregation in science as both sexes still follow the care/technology division trend in their disciplinary choices, which merits more attention.

KEYWORDS
Gender and science; higher education; vertical segregation; horizontal segregation; leaky pipeline; East Asia

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INTRODUCTION

Women's participation in science[1] has been a major concern among Western feminists since the 1970s. Although the "female advantage" phenomenon of how female students are doing increasingly better than male students in completing a college degree (Alon & Gelbgiser, 2011) has been discussed for the past two decades, vertical and horizontal segregations still persist and have a substantial impact on the occupational choices and career developments for women (Alon & Gelbgiser, 2011; Barone, 2010; Kumar, 2012; Macarie & Moldovan, 2015). The marginalization of women in certain disciplinary fields in higher education has led to their underrepresentation in science occupations and the decision-making positions (Huyer & Westholm, 2007). This is viewed as more than just a women's rights issue because the problem can also impede scientific innovations and developments by excluding or ignoring women's perspectives (Schiebinger, 2012; Wajcman, 2000).

To document and monitor the detailed status on gender equity, the United Nations called for sex-disaggregated data in all areas of development, including science and technology, during the 1995 Beijing World Conference on Women and the 1999 World Conference on Science. Another initiative calling for gender indicators in science was the 2003 World Summit on Information Technology. Since then, there has been a rapid increase of sex-disaggregated data generated by international agencies and nations that echoes the interest of women's engagement in science and technology activities (Huyer & Westholm, 2007). However, it is noteworthy that most agencies — even the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as well as the Organization for Economic Co-operation and Development (OECD) — have mainly adopted an "add-on" approach to sex-disaggregated data collection by adding a male/female distinction to the already existing standardized statistics (ibid.). Only the European Commission (EC) has invested more commitment in this regard.

In 2000, the EC formed a Women and Science Working Group (WSG) within the Commission under the Fifth Framework Programme (1998-2002) to coordinate actions that promote women's participation in European research. The WSG has collaborated closely with Eurostat — the statistical Office of EC — and the Statistical Correspondents of the Helsinki Group to develop a coherent system of gender-specific indicators, monitor the progress of gender equity in the fields of science, and facilitate cross-national comparisons. This collaboration resulted in the publication of *She Figures 2003*, which is referred to by the EC as the initiator of "a new era" that made sex-disaggregated data on human resources in the European Research Area possible (European Commission, 2010, p. 21). *She Figures* has been republished once every three years since then, and is one of the most important references for collecting sex-disaggregated data on personnel working in the science and technology fields worldwide.

Unlike Europe, cross-country comparison of gender and science data in East Asia (EA) remains rare (except for Lee & Kim, 2014; and KWSE, 2015, discussed later) despite the fact that science and technology developments have been the primary motivator for the postindustrial national economies in Japan, South Korea (hereafter "Korea"), and Taiwan. The idea to establish an East Asian network that promotes gender equity in science emerged in 2006 in light of the relatively similar social, cultural, and economic development status of these three countries.[2] It was initiated by the corresponding author of this paper and joined by feminist scholars from the three countries. Since January 2012, we have been working together to establish a comparable framework and collect statistics on higher education faculty members and students, and to more comprehensively depict gender segregation on university campuses in the three EA countries.

This paper is an initial contribution to the comparative empirical study on gender and science in the EA region. In the next section, we review some recent studies to provide an updated background for gender segregation in higher education. Then we briefly explain the data collection and classification process as well as the policy context for the three countries. Finally, we present the findings in three main parts. In the first part, we compare the gender composition along the academic pipeline (from undergraduate students to full professors) between the EU and the three EA countries to grasp the pattern of the EA region as opposed to Europe. The second and third parts comprise cross-time comparisons among the three EA countries for students and faculty members, respectively. In the conclusion section, we provide a brief summary and suggestion for future research.

RECENT STUDIES

The concepts of horizontal and vertical gender segregation are crucial in describing and monitoring the problems regarding the underrepresentation of women in various fields of science (Huyer & Westholm, 2007; Kumar, 2012, Meulders et al., 2010). In this paper, horizontal segregation refers to the underrepresentation or overrepresentation of both sexes between the different study fields (Meulders et al., 2010); and vertical segregation refers to the "decreasing percentages of women scientists compared to their male counterparts as the ranking hierarchy gets higher (BS to MS to PhD to faculty with higher faculty ranks)," a phenomenon commonly described as the "leaky pipeline" (Rosser, 2004, p.61). It is important to note that the "leaking" patterns for different disciplines are not the same.

Recent studies and reports have shown that women in general are not necessarily underrepresented in higher education, particularly in more industrialized countries. An OECD report titled "The Reversal of Gender Inequalities in Higher Education: An On-going Trend" (Vincent-Lancrin, 2008) described the rapid increase of female participation in higher education in OECD member countries (up to 55% on average) and argued that "in promoting equal opportunities for men and women, the focus can no longer be solely on women" (ibid. 265). Alon and Gelbgiser (2011) also indicated that female students are having better chances of applying, enrolling, and attaining a college degree than male students in the U.S.A. In 2011-2012 a large-scale survey conducted in the U.S.A showed that on average 60% of the

Master's Degrees and 52% of the PhD Degrees have been awarded to women (Gonzales, Allum, & Sowell, 2013). Finally, the recently published *She Figures 2015* (European Commission, 2016a) also indicated that women accounted for 59% of the Bachelor and Master graduates and 47% of PhD graduates in the EU-28 countries in 2013.

However, further cross-field analyses immediately revealed that the problems of horizontal and vertical segregation still persist. Take the EU-28 as an example. Although 47% of all PhD graduates were female, the ratios vary across fields of study with the highest ratio of 63% in Education and the lowest ratio of 28% in Engineering, Mathematics, and Computing (European Commission, 2016a; Macarie & Moldovan, 2015). The patterns are similar for the Master and PhD graduates in the U.S.A. At the Master's level, women are the dominant majority in Health Sciences (81%), Public Administration and Services (77%), and Education (76%); but accounted for only 23% in Engineering. At the PhD level, then, women are still the majority in Health Sciences (71%), Public Administration and Services (56%), and Education (68%), but the percentage of women in these fields has evidently reduced by 10% to 20% (Gonzales, Allum, & Sowell, 2013). Women "leaked" less in Engineering (22%), possibly because most of them have already dropped out before the Master's Degree phase, and the "survivors" are more determined to pursue their academic careers.

We may hence conclude that vertical segregation still exists but varies according to the fields of study. This is why Alon & Gelbgiser (2011, p.108) argued decisively that: "Today the main axis of gender inequality in higher education in the United States, as in all industrialized countries, is horizontal sex segregation across the fields of study." Macarie & Moldovan (2015, p.168) conducted an analysis of the EU-28 countries and made a similar assessment pointing out that although still observable, the evidence for vertical gender segregation is "less straightforward" than that of horizontal gender segregation. The reason vertical segregation is less straightforward is due to the different messages sent from different disciplines. This is a good direction of exploration for this research as the three EA countries are also in the developed context as the U.S.A. and most of the EU countries.

The horizontal segregation discussion can proceed much further after we break apart the existing disciplinary boundaries. Barone (2010) argued that such humanistic/scientific division standard is not sufficient to demonstrate the seriousness of the horizontal gender segregation because the gender imbalance is still quite different *within* the scientific and humanistic fields. He thus proposed to add a care/technology field division to the existing humanistic/scientific field division and argued that these two divisions accounted for over 90 percent of the associations between gender and academic choice altogether (ibid. p.158). Barone used this framework to make comparisons across eight European countries within a three-decade timeframe, and concluded that gender segregation is still highly resilient and universal not only due to the internalization of sex stereotypes in most societies, but also because stereotype is still backed-up by the development of service economies that are "functionally and symbolically similar to the women's traditional domestic roles....".That explained why "the Nordic countries are as gender-segregated as the Mediterranean countries" (ibid. p.173). Although the *explanations* of universal gender segregation across national and cultural differences are beyond the scope of this paper, Barone's cross-time comparison is a good reminder that we should assess the rate of change throughout a period of time.

In the discussion above, it was not our intention to investigate just the studies conducted in Western countries. However, it has been difficult to find any similar literature written in English that focused on gender segregation statistics in an East Asian or Asian context. One exception is the recent two waves of joint survey on the Asia and Pacific Nations Network (APNN) member countries (KWSE, 2015; Lee & Kim, 2014). The reports cited some statistics about these APNN countries from UNDP and UNESCO, and more importantly, presented first-hand survey results of the subjective perceptions on gender inequality for female scientists as well as the governmental policies and programs in these countries that promote gender equality in the STEM fields.

Although the size of the samples for each country in the two waves of survey was relatively small (approximately 100 responses each) and may affect the validity of the subjective indicators, such cross-country comparison in the Asian context is still a good start. In this study, we offer another aspect of contribution by directly collecting the governmental statistics from the three EA countries to provide a more accurate and detailed estimation of the gender and science status within this region. In addition, unlike most of the studies mentioned above that either focused on higher education students or scientific researchers, we combine the statistics from both populations to present a more comprehensive trend along the academic pipeline.

METHODS & BACKGROUND

The statistical data of the three EA countries were collected from the national educational agencies in each country, including the School Basic Survey and the School Teachers Survey from the MEXT (Ministry of Education, Culture, Sports, Science and Technology) in Japan; the 2004 and 2014 Statistical Yearbook of Education downloaded from Statistical Published Materials from MOE (Ministry of Education) in Korea; and Graduates in Tertiary Education and Full-time Teachers in Tertiary Schools from the MOE (Ministry of Education) in Taiwan. The EU-28 data were directly drawn from *She Figures 2015* (European Commission, 2016a). There are two issues that we must address regarding our data. The first issue is the year of the data. The statistical data in *She Figures 2015* were primarily from 2012 and 2013, and occasionally from 2014. Since the data among the EU countries were not necessarily from the same year, we have decided to use the more updated data from 2014 among the three EA countries and compare them with the 2012 or 2013 EU-28 data. In terms of cross-time comparison, we compare the 2014 data with the 2004 ones among the three EA countries to assess the changes in a decade.

The second issue is data reclassification. In *She Figures 2015,* higher-education students were classified into 2 levels and 7 broad fields of study, which was a slight revision to the 1997 International Standard Classification of Education (hereafter

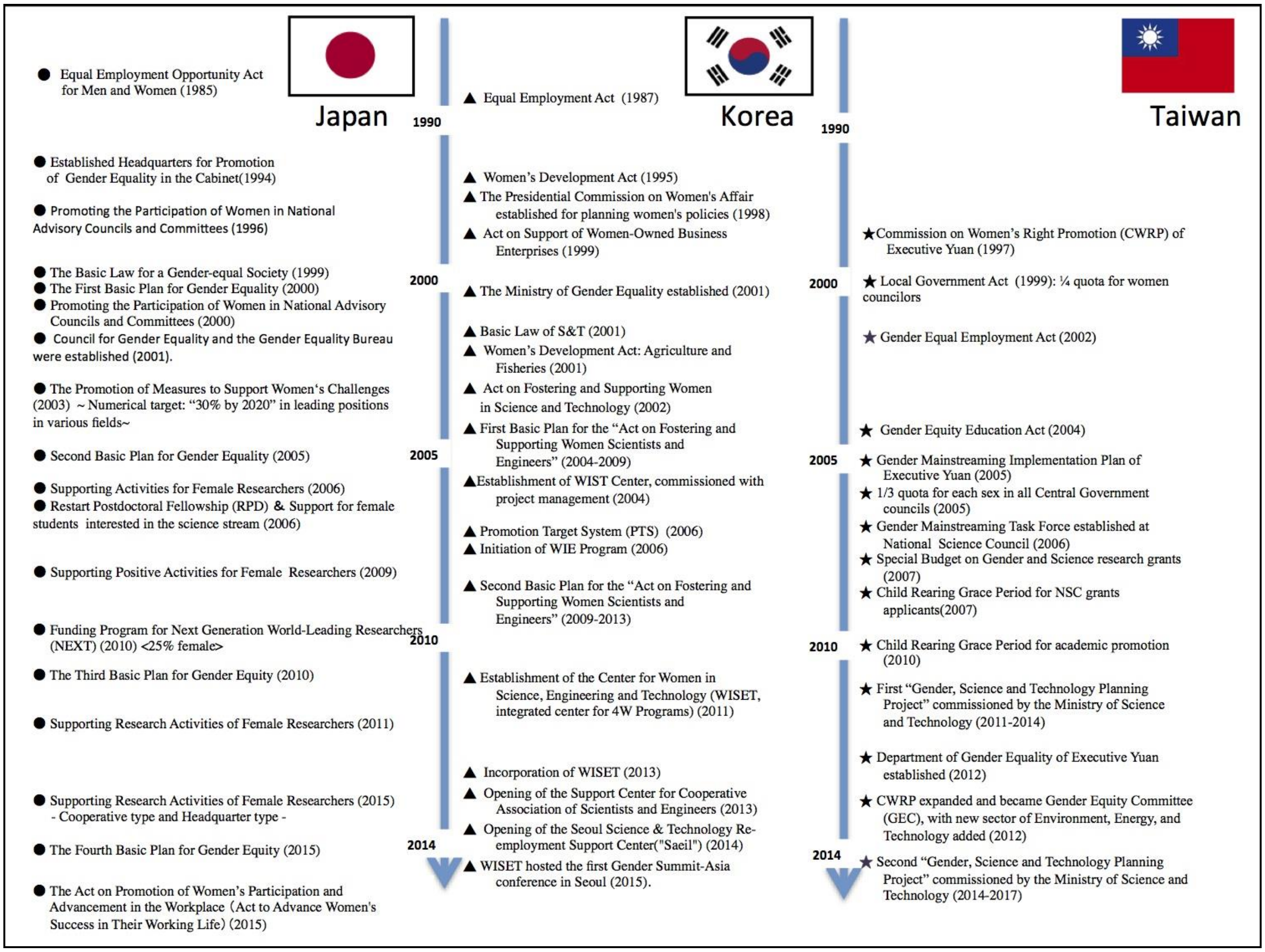
ISCED 97).[3] The faculty members, on the other hand, were classified into 3 grades and 6 fields of science in accordance with the *Frascati Manual* (OECD, 2002) and the 1976 International Standard Classification of Education (hereafter ISCED 76).[4] In order to be comparable with the EU statistics, as well as to be comparable with each other, the data from the three EA countries needed to be reclassified according to the above-mentioned standards.

The data from Taiwan were exempt from reclassification because the MOE in Taiwan has already disaggregated the data of the university students and faculty members in accordance with both ISCED 76 and 97. The data from Korea and Japan were not completely classified in this vein, but the authors were able to finish the reclassification task according to their original institutional titles based on the clear definition and illustration of the sub-disciplines in each broad field of study in ISCED 76 and 97. Unfortunately, the faculty data in Japan was not cross-classified by sex/grade/subfield, so we were not able to present a cross-field analysis for the faculty composition in Japan. In addition, as it is hard for Japan and Korea to reclassify the existing institutions (students) into the field of Service, we have decided to delete the category from this paper.

We acknowledge that there would be some unavoidable discrepancies in the reclassification process because of the different school systems or even definitions for colleges. For example, the data for those who have graduated via correspondence courses in Japan were not available, and government agencies schools such as the National Defense Academy were not included in the governmental statistics despite the fact that some of them are considered as higher education institutions. But we do believe that the number of these special or unclassifiable cases was not significant and should not affect our general analysis. There is a relatively serious limitation that we must address: we were only able to collect data based on the domestic graduates. There are a significant percentage of PhD students, particularly in Korea and Taiwan, who have received their degrees from the U.S.A. or European countries throughout the last decade. As the governments of the three countries do not collect or include data for this population in their official databases, we have no choice but to accept this limitation. However, please note that even *She Figures* did not include data on the number of students who have graduated from abroad (European Commission, 2016b:9).

Before presenting our findings, it is imperative to briefly introduce the gender and science policy backgrounds for each of the three EA countries. Figure 1 shows the milestones of gender (and science) initiatives in the three EA countries. It is clear that the *gender equality* machinery and the gender equal-employment legislations are present in all three EA countries that served as the basis for subsequent initiatives. However, in terms of *gender and science* development, the relevant legislations and mechanisms of Korea have evidently surpassed those of Japan and Taiwan.

Figure 1: The milestones of Gender and Science initiatives in Japan, South Korea, and Taiwan



Source: Collected and organized by this research.

In Japan, the percentage of women doing research in STEM fields is low compared to other countries (Homma, Motohashi, & Ohtsubo, 2013; Kodate & Kodate, 2016). Since the early 2000s, researchers' associations have played an active part in realizing the nation's commitment to the problem. Especially EPMEWSE (Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering) has carried out the Large-Scale Surveys on Gender Equality in STEM once every five years[5] and made proposals and requests to the Government. Accordingly, the Second Basic Plan for Gender Equality, and the Third Science and Technology Basic Plan focused on these problems. The Ministry of Education, Culture, Sports, Science and Technology has administered programs aiding institutions to increase the percentage of female researchers and develop family-friendly environments for researchers since 2006. Meanwhile, some challenges still require attention: a radical reassessment of work-life balance, under-representation of women in senior positions, sluggish growth in the number of female students nationwide, a very low rate of female researchers in the business sector, a lack of understanding of positive action, and sustainability of the programs (Yokoyama, Ohtsubo, Ogawa, Kawano, & Takarabe, 2016). It was only in 2015 that the Act on Promotion of Women's Participation and Advancement in the Workplace was passed, though the impact of this law and related policy measures is beyond the scope of this paper.

Similarly to Japan, there is a lack of formal legislation and institutionalized mechanisms for gender and science in Taiwan. Due to the internal pressure from women's movements and feminist scholars, as well as the external expectation from APEC (Asia-Pacific Economic Cooperation) on its member economies to promote gender mainstreaming, the government has applied the Gender Mainstreaming policy framework since 2005 (Peng, 2008). It led to the establishment of the Department of Gender Equality in the Executive Yuan in 2012 to serve as the highest-level gender policy machinery in Taiwan. Yet the machinery is expected to support and monitor the gender-equality efforts across all ministries and agencies. The main agency that promotes gender equality in science is the Gender Mainstreaming Task Force of the Ministry of Science and Technology (formerly National Science Council), which is merely an advisory committee comprising of government officials and feminist experts, and lacks resources or staffing to sustainably plan and implement relevant policies. Indeed, the task of planning "gender and science" policies so far was primarily conducted in the form of two commissioned projects—one from 2011 to 2014 and the other 2014 to 2017. It would be hard to create political and substantial policy influences in this way (Wu, 2012).

In contrast, Korea's 2002 *Act on Fostering and Supporting Women in Science and Technology* served as a solid foundation to the successive programs and Basic Plans that targeted women and science, and eventually led to the establishment of the WISET (Center for Women In Science, Engineering, and Technology) in 2011 (Lee, 2009; Leggon, McNeely & Yoon, 2015). The WISET provides a comprehensive support system toward fostering and employing women in Science, Engineering, and Technology (SET) fields, including different programs targeting secondary schools for women, undergraduate and graduate students, as well as women scientists and engineers. Despite being primarily framed in the discourses of national competitiveness and human resource development (Leggon, McNeely & Yoon, 2015), the resources and targeted efforts toward gender and science development in Korea may have explained Korea's better progress among the three EA countries, as would be shown later.

A GENERAL COMPARISON BETWEEN EU and EAST ASIA

In this section, the average data of EU-28 from *She Figures 2015* were used to compare with the average data from the three EA countries in order to distinguish the differences between the two regions in terms of the women's participation in various fields of science. Figure 2 shows the proportions of women and men in a typical academic career. The diagram of EU-28 represents a typical "Scissors Diagram" in which the proportion of women is *higher* than that of men at the ISCED 5A level, but the trend reversed at the ISCED 6 (PhD) level. The gender gap then increased for the higher-level positions, which illustrated how women are underrepresented at the higher-level positions throughout academia, and hence vertical segregation.

The diagram of the three EA countries actually showed a similar pattern and slope compared to that of the EU. The primary difference is that the EA diagram started with a more balanced proportion of male (52.2%) and female (47.8%) students at the ISCED 5A level, whereas the EU starts with 41% male and 59% female. This means that women are indeed doing *better than* men in the EU at the Bachelor and Master level, but at most *equally well* with men in EA. However, men have significantly surpassed women at the PhD level in both regions; and the higher the academic ladder, the more pronounced the phenomenon.

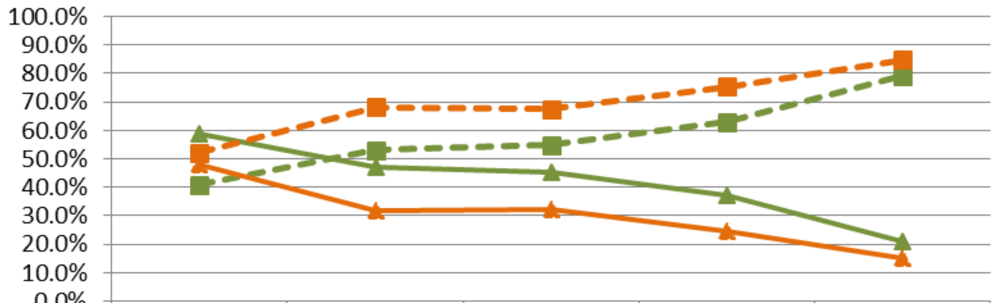
Figure 2 is a classic demonstration of vertical segregation and Figure 3 shows the horizontal segregation using the fields of science and engineering (S&E) as an example. In Figure 3, the EU and EA diagrams are similar in the sense that they both change from a scissor pattern to a "chopsticks" pattern, or two parallel lines of men and women. The gaps between the two genders at each and every stage along the academic pipeline are wide from the beginning and even wider at the end. That is, women have dropped off the S&E academic fields way before the university stage, and the gap is the largest at the full professor (Grade A) level.

However, the two diagrams are evidently different in two ways. First, the gap between the lines for the two genders in EU is narrower than that in EA, meaning that EU has less segregation between men and women in science than in EA. The second difference is the unique rise—as opposed to the "leakage"—of the women's percentage from the ISCED 6 (PhD) to the Grade C faculty (assistant professor) levels in the EA countries. This can probably be explained by the preference of female PhDs for the higher education sectors over their male counterparts in the EA context (Peng, Juang & Ho, 2016), but further studies are needed to assess this uncommon rise in detail.

At any rate, when Figures 2 and 3 are compared, it is clear that the participation rate for women is lower in the S&E fields than the averages of all fields, which demonstrated the existence of a horizontal segregation and showed that the source of segregation started way before the students have entered higher education. It is also noteworthy that the segregation situation in EA is clearly more severe than that in EU.

A further comparison within the Science *and* Engineering fields revealed more information regarding the source of gender segregation. Figure 4 shows the percentages of female PhD graduates and full professors (out of all PhD and full professors respectively) in Science, Mathematics and Computing (hereafter Science) as well as in Engineering, Manufacturing and Construction (hereafter Engineering) for the two regions. There are two common characteristics within the two regions according to the comparison. First and not surprisingly, women are doing better in Science than in Engineering, which implies the need to analyze these two disciplines separately for discussions regarding horizontal segregation. Second, women's participation in Science and in Engineering at the PhD level is far better than that for the full professor level. This may imply the existence of a resilient vertical segregation, but may also be seen as a sign of progress from the new generation.

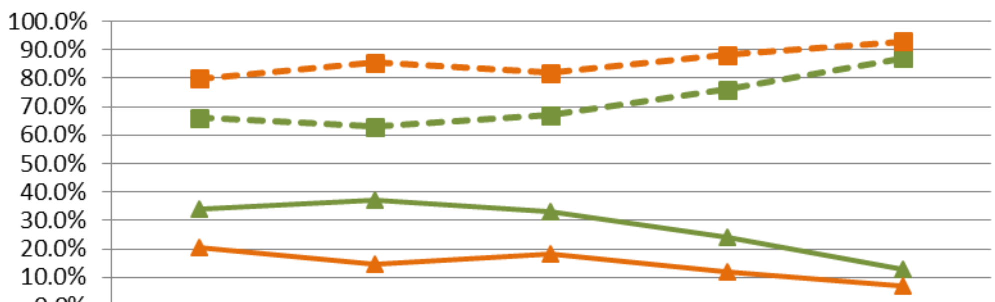
Figure 2: Proportions of women and men in a typical academic career, EU-28 (2013) vs. EA (Japan, Korea, and Taiwan average, 2014)



	ISCED 5A (graduates)	ISCED 6 (graduates)	Grade C	Grade B	Grade A
2013(M) EU-28	41.0%	53.0%	54.9%	62.9%	79.1%
2013(F) EU-28	59.0%	47.0%	45.1%	37.1%	20.9%
2014(M) EA	52.2%	68.1%	67.6%	75.4%	84.8%
2014(F) EA	47.8%	31.9%	32.4%	24.6%	15.2%

Sources: EU-28 data from *She Figures 2015* (EC, 2016a, p.127, 129); EA data collected by this research.

*Figure 3: Proportions of women and men in the Science and Engineering academic career, EU-28 (2013) vs. EA (Japan, Korea, and Taiwan average, 2014)**

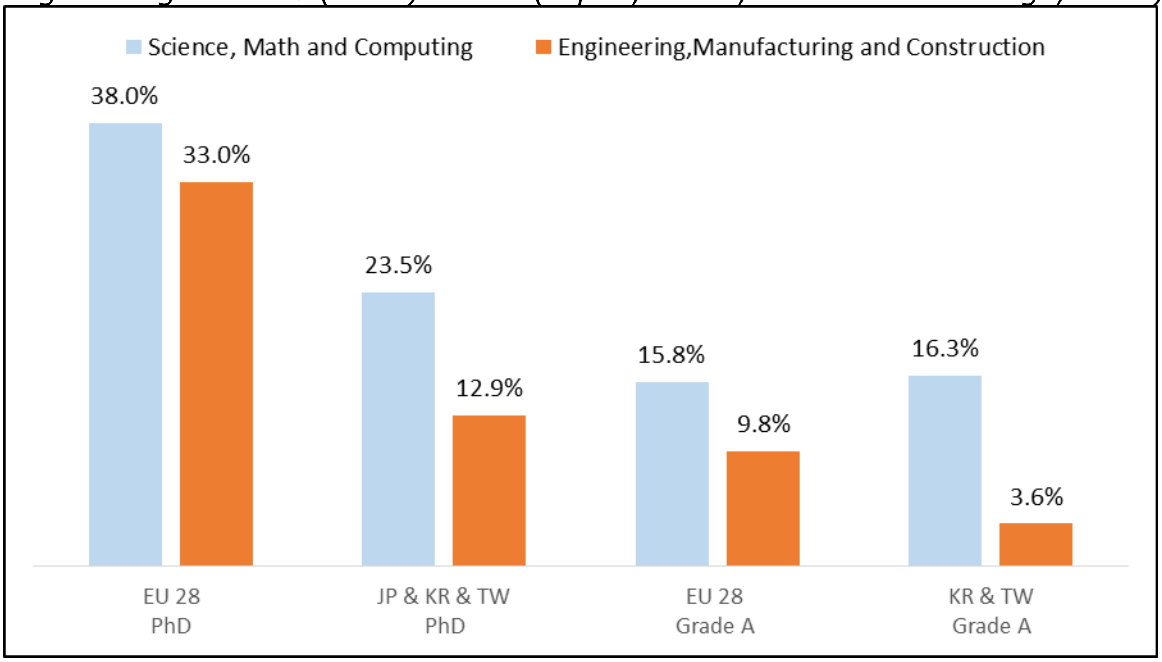


	ISCED 5A (graduates)	ISCED 6 (graduates)	Grade C	Grade B	Grade A
2013(M) EU-28	66.0%	63.0%	67.0%	76.0%	87.0%
2013(F) EU-28	34.0%	37.0%	33.0%	24.0%	13.0%
2014(M) EA	79.7%	85.4%	81.7%	88.2%	92.9%
2014(F) EA	20.3%	14.6%	18.3%	11.8%	7.1%

Sources: EU-28 data from *She Figures 2015* (EC, 2016a, p.128); EA data collected by this research.
* There in no data in Japan on the percentage of male and female faculty in the S&E fields, so the EA numbers for the Grade A, B, and C faculties here is the average for only Korea and Taiwan.

The difference between the two regions is primarily the extent of the gap. While in the EU, the women's PhD percentage in Engineering is slightly lower than that in Science (33% vs. 38%), the women's percentage in Engineering is only 1/2 of that in Science (13% vs. 24%) in the EA countries. Worse still, while women's participation as full professors in Engineering is much lower than in Science, the gap in the EA (4% vs. 16%) is significantly larger than that in EU (7% vs. 16%). In short, the comparison shows that EA countries face a much more severe horizontal segregation challenge than EU, particularly in the field of Engineering.

Figure 4. Female PhD and Grade A faculty (full professor) in science vs. in engineering: EU-28 (2012) vs. EA (Japan, Korea, and Taiwan average, 2014)*

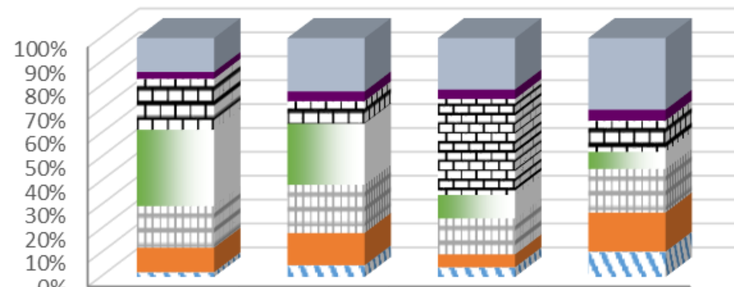


Sources: EU-28 data from *She Figures 2015* (EC, 2016a, p.31); EA data collected by this research.
* The denominator of the female PhD percentage for each bar is the male and female PhD sum in Science or in Engineering. The denominator of the female Grade A percentage is the male and female Grade A faculty sum in Science or in Engineering.

Horizontal segregation occurs in more fields than just Science and Engineering (Barone, 2010; Meulders et al., 2010). Figure 5 uses a different method of comparison to exemplify the horizontal segregation in other fields of study. Instead of contrasting the ratios for the two genders within each single field of study, we calculated the distribution pattern of female PhDs among all fields of study (except for the Service field due to the lack of data) and contrasted the results with the men's distribution pattern among all fields of study. We also compared the pattern differences between the EA countries and EU-28.

Figure 5 clearly shows that women PhDs in EU and EA have greater chances to graduate from fields of Health & Welfare, Humanities & Art, and Education; whereas men PhDs have greater chances to graduate from Engineering and Science fields. These disproportionate distributions echo the argument by Barone (2010) on the stereotypical care/technology divide between the two genders in higher education, and remind us that the problems of gender participation in science would soon refer to not only the male-dominated Engineering and Science fields, but also a growing number of female-dominated fields as well. In terms of regional comparison, Figure 5 again shows that horizontal segregation in either male-dominated or female-dominated fields in the EA countries is more severe than that in EU.

Figure 5: Proportion of PhD students within single sex, disaggregated by fields of study, EU-28 (2012) vs. EA (Japan, Korea, and Taiwan average, 2014)



	EU-28 Men	EU-28 Women	East Asia Men	East Asia Women
Health and welfare	14.2%	22.4%	21.5%	30.0%
Agriculture and veterinary	2.9%	4.0%	4.0%	4.6%
Engineering, manufa. + cons.	21.3%	9.4%	40.2%	13.1%
Science, math. + compu.	31.9%	25.7%	9.9%	7.2%
Social sci., business + law	17.5%	20.1%	15.0%	18.2%
Humanities and arts	10.2%	13.5%	5.4%	16.4%
Education	2.0%	4.9%	4.1%	10.6%

Sources: EU-28 data from *She Figures 2015* (EC, 2016a, p.38); EA data collected by this research.

CROSS-TIME COMPARISON OF STUDENTS IN THE THREE EAST ASIAN COUNTRIES

In this section, we reveal and compare the changing patterns of gender segregation in the composition of students who have graduated from universities in Japan, Korea, and Taiwan between 2004 and 2014. To better demonstrate the sources of gender segregation, we split the category ISCED 5A graduates into graduates with Bachelor's and Master's degrees, and tracked the ratio changes for male and female students along the three levels of degrees (Bachelor, Master, and PhD) to compare the trends among the three EA countries and provide a cross-time comparison to assess the sign of progress in the past decade.

Figure 6 shows the proportions of women and men awarded with the three levels of degrees in all fields of study throughout the three EA countries. A comparison of the 2004 and 2014 diagrams clearly indicated that Korea and Taiwan have demonstrated similar patterns in two aspects. First, they both showed more equal starting-points at the bachelor's level in 2004. That is, the percentages of men and women bachelors in these two countries were already balanced a decade ago. Second, the two countries showed similar and evident progress in the past decade, as demonstrated by the overlapping points for men and women from the Bachelor's to the Master's levels. That is, after a decade's efforts, the two countries now enjoy a relatively gender-balanced distribution of men and women at the Master's level, and Korea is doing even better than Taiwan. The vertical gender segregation problem faced by Korea and Taiwan lies primarily at the PhD graduate level.

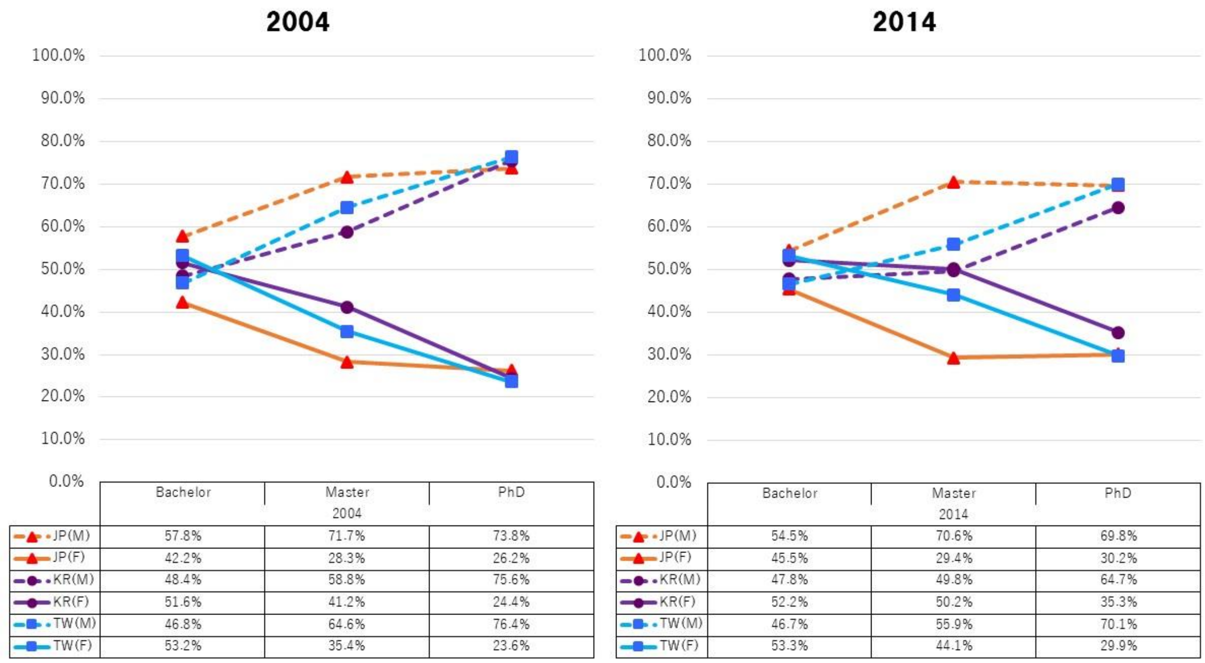
Compared to Korea or Taiwan, it is a surprise to see the slow progress of Japan for the past decade. Japan already had a comparatively wider gender gap for the Bachelors back in 2004, and the gap reduced only moderately in the past decade. This means that the academic vertical gender segregation in Japan actually occurs *before* higher education. The gap continued to widen from the Bachelor's Degree level to the Master's Degree level, meaning that women have dropped out of academia earlier than men after they received a Bachelor's Degree, and the trend continued almost unchanged for the past decade.

However, we noticed the relatively flat slope for the line between the Master's Degree and the PhD levels in Japan, which implies less leakage (even a slight increase as in 2014) of the Japanese female students at the PhD level. That is, there is a higher chance for Japanese female Master's Degree graduates to continue on to pursuing a PhD degree in comparison with those from Korean and Taiwan. However, it has been pointed out that the international female students have increased the PhD ratio for female students (Kato & Chayama, 2012). At any rate, to tackle the problem of vertical segregation for higher education students in Japan, more efforts must be focused on the university entrance rates and post-university graduate school entrance rates for women.

After examining the different patterns of vertical segregation from the three countries in terms of students in higher education, Table 1 further enables us to assess the different degree of horizontal segregation using data disaggregated by sex and fields of study at the PhD level. The ratio of female PhD graduates across fields of study demonstrates horizontal segregation that we already discussed in Figures 3-5, and will not be repeatedly analyzed here. Instead, we applied the "compound annual growth rate" (hereafter CAGR)[6] formula to the raw numbers for PhD graduates to calculate the growth rates of male and female PhDs in different fields of study from 2004 to 2014. On average, the result showed that female PhDs are growing at a higher rate than male PhDs in all three countries for the past decade, with Korea enjoying the highest rate of growth.

Although the number of PhDs for women increased more than men in almost all disciplines in all three countries in general, we have distinguished the different paces and patterns among the three countries. In Japan, the growth rates for both male and female PhDs in every field of study are mostly negative or relatively low, with the only exception of PhDs awarded to women in Engineering (5%, the highest growth rate in Japan).

Figure 6. Proportions of women and men awarded with three levels of degrees in all fields of study: Japan, Korea, and Taiwan (2004 vs. 2014)



2004

	Bachelor	Master	PhD
JP(M)	57.8%	71.7%	73.8%
JP(F)	42.2%	28.3%	26.2%
KR(M)	48.4%	58.8%	75.6%
KR(F)	51.6%	41.2%	24.4%
TW(M)	46.8%	64.6%	76.4%
TW(F)	53.2%	35.4%	23.6%

2014

	Bachelor	Master	PhD
JP(M)	54.5%	70.6%	69.8%
JP(F)	45.5%	29.4%	30.2%
KR(M)	47.8%	49.8%	64.7%
KR(F)	52.2%	50.2%	35.3%
TW(M)	46.7%	55.9%	70.1%
TW(F)	53.3%	44.1%	29.9%

Source: Data collected and calculated by this research.

Taiwan shows the opposite trends compared to Japan in that both male and female PhD numbers have grown in the past decade, with women growing at a rate of 1% to 4% higher than men in almost every discipline. One exception is in Engineering, where the rate for women grew by 12.3% but the rate for men only grew by 4.6%. The other exception is Health and Welfare, where the PhD growth rate for male is 0.4% higher than that for women, showing a good sign of segregation reduction in this particular female-dominated discipline.

Korea again shows a significant progress in terms of the women's participation in science according to Table 1, whereby the rate of PhDs for women is growing much more rapidly than that of men in almost every discipline, and the gap ranged from 7% to 11%. It is noteworthy, though, that Korea has the highest ratio of female PhDs in Humanities (70.2%) and Education (68.0%), but also the lowest ratio of female PhDs in Engineering (9.9%) among the three countries. That is, the problem of horizontal segregation is arguably more serious in Korea than in the other two countries. Although the growth rate of female PhDs in Korea implies a reduced vertical segregation, it also conveys a greater potential for horizontal segregation in that the number of female PhDs is growing more rapidly in the female-dominated disciplines than the number of male PhDs.

Table 1: Compound annual growth rate (%) of PhDs disaggregated by sex and fields of study. Japan, Korea, and Taiwan, 2004-2014

	Japan			Korea			Taiwan		
	2014 Female PhD,%*	M	F	2014 Female PhD,%	M	F	2014 Female PhD,%	M	F
All FIELDS average	30.2%	-0.5%	1.5%	35.3%	0.7%	6.8%	29.9%	5.4%	8.8%
-Education	44.9%	2.9%	1.5%	68.0%	3.9%	11.0%	45.8%	8.3%	9.6%
-Humanities & Arts	50.3%	-1.6%	-0.9%	70.2%	-7.2%	4.6%	54.0%	5.7%	7.6%
-Social Science, Business & Law	36.0%	-1.9%	0.7%	33.7%	5.4%	14.8%	41.1%	4.2%	7.7%
-Science, Math. & Computing	17.5%	-0.8%	-0.8%	25.9%	-20.7%	-19.6%	27.1%	5.7%	7.7%
-Engineering, Manufacturing & Construction	15.8%	-0.2%	5.0%	9.9%	4.4%	11.4%	13.1%	4.6%	12.3%
-Agriculture and Veterinary	35.3%	-3.1%	0.7%	27.6%	-1.7%	7.8%	34.7%	3.9%	5.3%
-Health and Welfare	32.4%	0.2%	2.4%	45.8%	-1.4%	5.9%	44.3%	10.1%	9.7%

Source: Data collected and calculated by this research.
* The denominator for the female PhD percentage is all (male + female) PhD members in that specific grade and field.

CROSS-TIME COMPARISON OF FACULTY MEMBERS IN THE THREE EAST ASIAN COUNTRIES

The last section of our research findings focuses on the faculty members in higher education; namely, the male and female composition of full professors (Grade A), associate professors (Grade B), and assistant professors (Grade C) in the three EA countries as well as the progress in the past decade. Figure 7 shows a downward slope of female faculty ratio from Grades C to A, a typical representation of the leaky pipeline. Among the three countries, the line for Taiwan is relatively ahead of the other two, which indicates a higher ratio of women faculty members compared to those for Korea and Japan at all three levels in either 2004 or 2014.

A comparison of the lines between 2004 and 2014 reveals the three EA countries have indeed made progress. Table 2 further illustrates what the progresses were by showing the CAGR calculated using the raw numbers. It is evident that the number of female faculty members at all three levels in all three countries have been growing at a higher rate than their male counterparts, but at different paces. The growth of female senior professors in Japan is slightly higher than that for the junior faculty members. However, the trend is opposite in Korea, where the rate of growth for female assistant and associate professors is much higher than that for full professors. The rate of growth for female faculty members in Taiwan at all three levels are relatively close, and exceeded male faculty members by a 3.5% to 4.5%

gap. In short, the growth rates of female and male faculty members in the past decade reveal a continuously decreasing gender gap and vertical segregation.

Figure 7. Proportions of women in each grade of faculty members. Japan, Korea, and Taiwan, 2004 vs. 2014

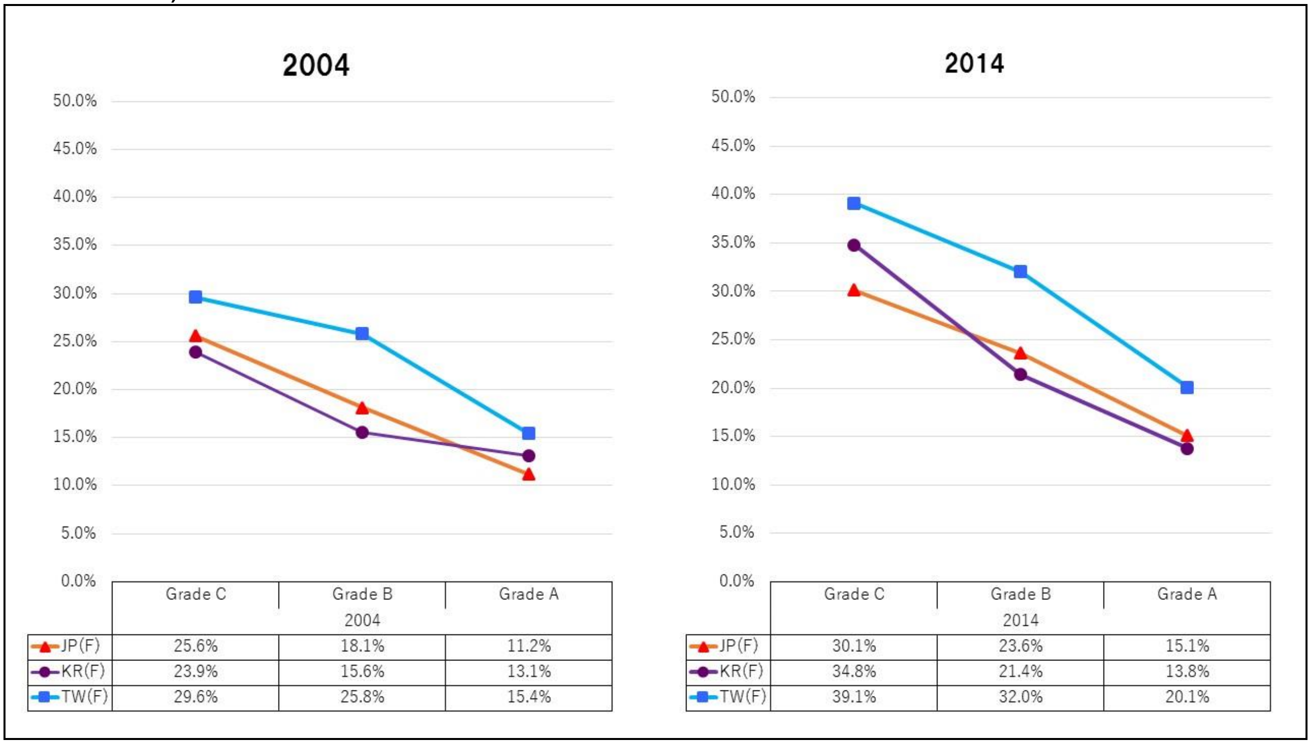


Table 2: Compound annual growth rate (%) of faculty members disaggregated by sex and grade. Japan, Korea, and Taiwan, 2004-2014

	Japan		Korea		Taiwan	
	M	F	M	F	M	F
Grade A	0.1%	3.6%	3.2%	3.8%	3.2%	6.6%
Grade B	0.3%	3.7%	1.2%	5.3%	1.3%	4.4%
Grade C	-0.2%	2.0%	0.6%	6.1%	2.7%	7.2%

Source: Data collected and calculated by this research.

Finally, we can also achieve a better understanding of the horizontal segregation status among faculty members via cross-field comparison. Due to the lack of the faculty data disaggregated based on the fields of research from Japan, we can only calculate and compare the data from Korea and Taiwan as shown in Table 3. We provided the ratio of female faculty in each discipline to better interpret the CAGR. According to the 2014 female faculty ratio, it is clear that women faculty members are least represented in Engineering and most represented in Medical science and Humanities in both countries.

Table 3. Compound annual growth rate (%) of faculty members disaggregated by sex, grade, and field of research. Korea and Taiwan, 2004-2014.

		Korea			Taiwan		
		Female ratio, in 2014 (%)*	CAGR		Female ratio, in 2014 (%)	CAGR	
			M	F		M	F
NS Natural sciences	Grade A	15.4%	3.6%	6.5%	17.2%	2.7%	5.4%
	Grade B	22.7%	1.1%	4.8%	22.3%	2.7%	5.6%
	Grade C	33.2%	1.8%	7.3%	23.9%	2.2%	5.5%
ET Engineering & technology	Grade A	2.2%	5.4%	11.1%	5.0%	4.5%	8.5%
	Grade B	5.6%	0.7%	10.9%	8.9%	0.3%	5.2%
	Grade C	10.3%	-1.4%	4.0%	13.6%	-0.8%	5.8%
MS Medical sciences	Grade A	19.7%	4.5%	6.5%	29.4%	4.1%	8.8%
	Grade B	30.1%	3.0%	7.7%	42.2%	1.4%	4.4%
	Grade C	50.4%	-1.4%	6.6%	50.1%	3.2%	9.3%
AS Agriculture sciences	Grade A	4.0%	-0.4%	0.8%	18.8%	0.6%	7.5%
	Grade B	6.1%	-2.8%	3.1%	26.2%	0.8%	2.3%
	Grade C	18.0%	-2.8%	7.7%	28.8%	2.8%	4.1%
SS Social sciences	Grade A	8.4%	0.6%	-2.1%	28.2%	2.4%	5.2%
	Grade B	18.4%	0.3%	3.8%	38.8%	0.7%	3.1%
	Grade C	30.8%	0.6%	5.0%	43.9%	2.3%	5.9%
H Humanities	Grade A	25.3%	2.4%	3.9%	39.3%	1.8%	7.8%
	Grade B	31.8%	1.7%	4.9%	50.2%	2.7%	4.7%
	Grade C	40.1%	3.1%	7.0%	51.8%	7.5%	8.1%

Source: Data collected and calculated by this research.
* The denominator for the female faculty percentage is all (male + female) faculty members in that specific grade and field.

The CAGR figures for Korea and Taiwan shown in Table 3 reveal three common trends identical to those of the higher education graduates discussed earlier. First, women faculty members grew at higher rates than those male faculty members at almost every level and every discipline except for the Grade A faculty of Social Science in Korea. This implies that fewer women are dropping out of the academic pipeline and hence less vertical segregation in all fields. Second, although Engineering is one of the most rapidly growing disciplines for female faculty members (which may result in a gradual decrease of horizontal segregation in this aspect), the growth rate at Grade A level is higher than that for Grade B and C levels. This finding merits our attention because the problem of horizontal segregation in Engineering would be deadlocked unless the percentage of junior female faculty members entering these fields has increased.

The third common trend of CAGR in Korea and Taiwan also evokes a similar concern. That is, the already "feminine" or "care-related" disciplines such as Humanities and Medical science also showed a rapid-growth of new entries by women, especially at the Grade C level. Although newly joined female faculty members do not "concentrate" on the already feminized fields of research, neither do they reverse or change the gendered pattern of career path. If the growth pattern stays unchanged and the problem of horizontal segregation continues, the gendered institutional structure and culture would be less likely to transform.

CONCLUSION

The low participation of women in science has been identified as an urgent global problem that must be resolved, but detailed pictures and comparative analyses of the problems in the East Asian countries are still rare. In this paper, we presented the collaborative efforts of the scholars from Japan, South Korea, and Taiwan in order to take one more step forward in this regard, and made three primary findings based on the comparisons discussed above.

First, we compared women's participation in science between the three EA countries and the EU-28 nations, and found that the problems of vertical and horizontal segregations are more pronounced in EA than in EU. We also pointed out that cross-field analysis is needed in order to truly capture the sources of segregations. For example, the field of Science should be separated from Engineering because the former is relatively gender balanced at the PhD level in both regions but the latter is still characterized by a sharp gender gap, particularly in EA where Engineering, Manufacturing and Construction remain the mainstream disciplines.

Second, when focusing on the *students* in the three EA countries, it is evident that the academic gender segregation in Japan occurs quite early in the educational process, even before the students have entered universities. In contrast, women in Korea and Taiwan tended to exit from higher education just prior to the PhD level. On average, the number of women PhDs has increased more significantly than that of men in all three EA countries throughout the past decade, with Korea having the highest growth rate. Yet the growth of the number of female PhDs does not necessarily contribute to the elimination of gender segregation as the number of women PhDs has been growing rapidly in the female-dominated disciplines and not in the male-dominated disciplines, and this trend merits more attention.

Third, in terms of faculty members in the EA countries, it is also evident that female faculty members have been growing at much higher rates than their male counterparts at each academic level in the past decade, which implies a continuously decreasing gender gap along the academic pipeline. However, similar to university graduates, the problem of horizontal segregation is likely to persist in the near future as the new faculty members of both sexes still follow the tradition of care/technology division throughout their academic paths. The origin of this problem needs to be traced back to before higher education even started.

In summary, we have contributed to the existing literature on vertical and horizontal gender segregations in higher education by adding the empirical data and analysis of East Asian countries. The evidence showed that the gender and science situation in the three EA countries has basically followed the patterns of the U.S.A. and the EU nations in terms of decreasing vertical segregation as well as stabilizing, if not increasing, trend of horizontal segregation. South Korea has made better progress throughout the past decade compared with the other two EA countries, which may imply that profound changes require substantial and stable institutional support. Following up the primary findings of this research, we suggest that more detailed studies should be conducted on the impacts that systematic reforms and targeted programs (or the lack thereof) have on the participation of men and women in different fields of science.

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ENDNOTES

[1] We use the broader definition of “science” that includes social sciences and humanities (Meulders et al., 2010). When we specifically use the terms such as Natural Science or STEM (Science, Technology, Engineering, and Mathematics), however, we are referring to the narrower definition of science in accordance with the ISCED classification for certain disciplines.

[2] The reason we choose Japan, Korea, and Taiwan for comparison is partly a result of the academic network as well as their relatively similar social, cultural, and economic contexts. The lack of data from China -the biggest country in East Asia- is indeed a limitation for this paper, but the path of development and magnitude of change in China’s economics and education systems have significantly distinguished China from the other three East Asian countries.

[3] This classification is based on the 1997 International Standard Classification of Education (ISCED 97). The 2 levels refer to ISCED 5A -Bachelor and Master studies in theory-based programmes (as opposed to more practically, technically or occupationally specific 5B category), and ISCED 6--PhD level. The 7 fields of study in *She Figures 2015* are: (1) Education, (2) Humanities and Arts, (3) Social science, Business and Law, (4) Engineering, Mathematics and Construction, (5) Agriculture and Veterinary, (6) Health and Welfare, and (7) Services. (European Commission, 2016b). This classification basically follows ISCED 97 except for omitting the first category in ISCED 97, or the (0) General Programmes (UNESCO, 2006).

[4] The 3 levels of faculty members (academic staff) in general refer to full professor (A), associate professor (B), and assistant professor (C). The 6 fields of science in *Frascati Manual* are: (1) Natural sciences, (2) Engineering and Technology, (3) Medical sciences, (4) Agricultural sciences, (5) Social sciences, and (6) Humanities. This classification is based on an earlier version of the International Standard Classification of Education,

namely ISCED 76 (OECD, 2002; European Commission, 2016b).

[5] The EPMEWSE reports of Large-Scale Surveys on Gender Equality in STEM in Japan can be downloaded at the following links:
the 2003 report: http://www.djrenrakukai.org/doc_pdf/EPMEWSEreport.pdf;
the 2008 report: http://www.djrenrakukai.org/doc_pdf/h19enquete_report_en.pdf;
the 2013 report: http://www.djrenrakukai.org/doc_pdf/3rd_enq_report_en.pdf.

[6] Compound Annual Growth Rate (CAGR) refers to the average annual rate of growth (g) of any indicator (I) between an initial year (year a) and a final year (year b) in percentage, which is calculated using the formula: g = [(Ib/Ia)1/(b - a) - 1] x 100. (European Commission, 2016a: 191).

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