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Women in STEM: Snapshots from a Few Asian Countries

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Abstract: Globally, we face several grand challenges that require multi-disciplinary, cross-boundary approaches for successful solutions and their implementations. Engineers and scientists play a large role in helping solve these complex problems. It is now widely accepted that an inclusive and diverse workplace inherently attracts top talent which is needed to solve the complex challenges that we face. In this context, note that although women make up almost 50% of the global population, they are greatly under-represented in engineering and many scientific disciplines. This under-representation is pervasive, with only a handful of exceptions. In this paper we focus on a few Asian countries presenting historical information regarding the first women's entry into the engineering profession, the current situation, and trends that can be observed from available data. The data and associated contexts show that progress in women's participation in science and engineering is linked to fast-paced economic development requirements as well as ideology and policies of the country.

Keywords: Diversity in the workplace, Women in engineering, Women in STEM, Gender gap, Socio-cultural, Socio-economic.

1. INTRODUCTION

In the current decade, global challenges and risks are at the forefront of both developed and developing nations. The World Economic Forum, in its 17th edition of the Global Risks Report (weforum.org, 2022) states that 84% of the Global Risks Perception Survey (GRPS) respondents were either concerned or worried about the outlook for the world. It identified the most severe risks on a global scale over the next 10 years as: "Climate action failure, Extreme weather, Biodiversity loss, Social cohesion erosion, Livelihood crises, Infectious diseases, Human environmental damage, Natural resource crises, Debt crises, Geo-economic confrontation." Globally, STEM (science, technology, engineering and mathematics) professionals play a large role in helping to solve many of these problems. High performance diverse teams are needed to successfully address these complex issues. This is the context in which we explore the role and participation of women in science and engineering fields in various countries.

In a previous paper we explored the status of women in STEM, particularly engineering, in the United States of America, Ireland, Bulgaria and Romania (Chowdhury, F.N., et al., 2021). This current paper continues that exploration but focuses on different countries: India, Japan, South Korea and Malaysia. A number of key questions are asked, including historical information on women's participation in science and engineering fields. We also consider political or social changes the country might have experienced that could influence national policies regarding science/technology education and workforce. In the next few sections we present snapshots from these four countries.

2. INDIA

Cliched, but true that any generalizations in India is a non-trivial multi-variate, multi-dimensional problem. In this paper, we focus on a few of the issues that are relevant to India in terms of women in STEM. Towards this, we present a case

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study on a cohort of female students undertaking a higher degree course in 'Foundations of Data Science' at the Birla Institute of Technology and Science, Pilani, India. All these students were industry professionals working in STEM with varied years of experience. This course was conducted during July- November 2021, with 364 students, about 25% female. Of these, 52 (61%) female students participated in our short, anonymous survey.

We summarize here the most interesting results of the survey. One question was whether it was easy for them to choose a STEM field at the undergraduate level; if not, was it due to factors such as remote locality, lack of infrastructure, or any other socio-economic factor. About 10.4% (of the 52) said they could not pursue the field of their choice. Out of these 10.4% respondents, around 23% cited familial reasons; 15.4%, societal reasons; 15.4%, lack of infrastructures in their locality; around 54% cited other external factors. One of the participants said: "Opportunities were available, but due to a mindset that STEM studies are expensive, I was not allowed to choose STEM. Also, there was a mindset that the environment of STEM colleges are [*sic*] not good." Another factor contributing to fewer women working or studying STEM could be the societal impression that girls are not as good in 'mathematics' as boys. To test this, we asked: "Generally in your society, locality, do you feel that girls assume that they would not do well in STEM and thus do not even make the effort?" 82.7% of the respondents said 'no', which is encouraging. For those responding 'yes', we asked: "has it always been this way in your area/society/locality? If yes, then have these things shifted for the better over the years?" Around 88% of the respondents said that there was significant improvement in societal outlook in their areas/localities over the years and in recent times. Some respondents added that the bias still exists widely, and much more needs to be done to overcome them. Lastly, we asked, "Generally, does your society respect and value careers in STEM?" Interestingly, 100% answered in the affirmative. Note that this question was gender independent and a contradiction for the respondents who had, in their responses, mentioned that their families were not happy for them to choose STEM fields. Indeed, some respondents had pursued non-STEM undergraduate programs because of family/social pressure. Thus, we observe a social structure with full confidence in STEM, and yet discouraging their female members to pursue these fields.

Despite societal resistance, India has produced women engineers and mathematicians since the mid-1940s (Chowdhury, F.N., 2022), (Gupta, R., 2021), albeit not in large numbers. After Indian independence in 1947, the Central Government adopted several schemes towards women's education in general, including higher studies in the arts and humanities (Komath, S.S., 2019). Progress has been made gradually over the decades: women are now well represented in STEM courses with a few exceptions, e.g. Mechanical Engineering. The gender distribution in students enrolled for courses in STEM is shown in Fig. 1. This is based on data collected during a 2019-20 pan India survey by the Ministry of Education (MoE, Govt. of India, 2020).

World Bank Data show that "there are more Indian female graduates (43%) in STEM at the tertiary level than in developed nations like the US (34%), UK (38%), Germany (27%) and France (32%)." (Agrawal S., 2021). This may be due to Government initiatives such as "Beti bachao beti padhao"--- a drive for literacy for the girl child (IBEF, Govt. of India); Samagra Siksha --- a programme to facilitate equal opportunities for education, with one of the goals being 'By 2030, eliminate gender disparities in education' (MHRD, Govt of India, 2018).

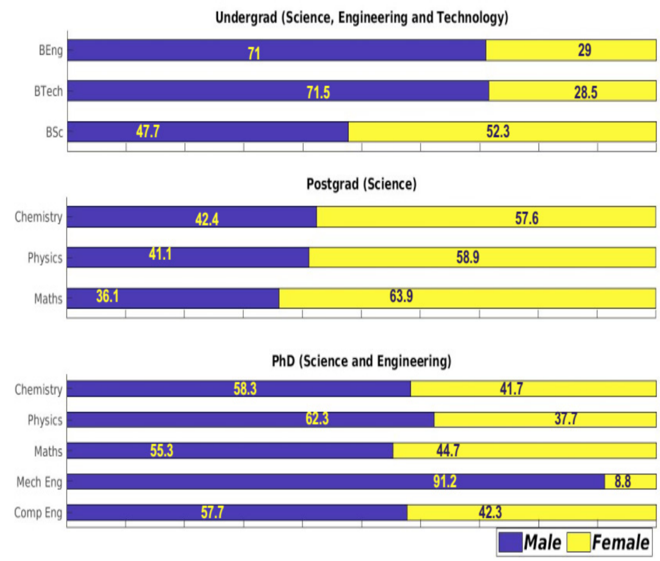

Fig. 1 Gender distribution in various STEM course enrollments in India (2019-20). Data sourced from (Ministry of Education, Govt. of India, 2020).

Although numbers of women enrolling in STEM subjects are not too low, there are reports stating "Indian women scientists are only 14% of the 280,000 scientists, engineers and technologists employed in research institutions in the country. For comparison, the global proportion of women is 30% amongst the world's scientific researchers." (Baruah, D., 2022). Our focused case study seems to be representative of the overall situation in India. The possible factors that we have discussed concerning under-representation of women in STEM jobs in India align with discussions elsewhere (for example see (Sharma, S., 2021)). Basic facilities such as Working Women's Hostels are still not considered safe, even in major industrial cities in India, not to mention smaller towns. The Government is taking initiatives in this regard (Muniraju and Attri, 2022), but a lot more must be done for successful implementation.

3. JAPAN

Despite all the cultural changes and progress in terms of gender equality, workplaces in Japan still discriminate based on gender and expect women to take different career paths and lesser roles than men. The Japanese government missed the target, set in 2003, of increasing the portion of women in leadership positions to at least 30% by 2020 in all fields in society and ranked 120th among 156 countries in the World

Economic Forum's Global Gender Gap Report released in March 2021, remaining in last place among major advanced economies in the world (Weforum, 2021).

The first female university students in Japan date back to 1913 when Tohoku Imperial University matriculated three women, all of whom majored in natural science. In 1927, a woman, Kono Yasui, received a doctoral degree in science for the first time. In the following years women enrolled and gained doctoral degrees in different fields, however, it was not until 1959 that a doctorate in engineering was conferred to a female. The 1960s can be regarded as the beginning of the history of female researchers in all STEM to have been systematically educated in Japan (Ogawa, M., 2017). However, Japan was and is still characterized by the patriarchal "male-breadwinner" model, in which the male, father and husband, earns money to support the others, while the female stays home as housewife, providing care for children and elderly. Hence, it is very difficult for women to find positions outside of this model (Osamu, S., 2014).

With the Law for Equal Employment Opportunity for Men and Women (EEOL) in 1986, women were officially recognized as an intensive part of the workforce. However, this law was more a reactive move to international pressure and did not bring consistent changes to the Japanese society; in fact women remained and are still underrepresented, especially in STEM (Kodate, N. et al., 2015). After more than 30 years, the situation remained unchanged and in 2020, Japan had the lowest share of women graduating in STEM (science, technology, engineering and mathematics) among the comparable Organization for Economic Cooperation and Development (OECD) member countries. In engineering, manufacturing and construction, women occupied only 16% in Japan, while the OECD average was 26% (OECD., 2020). The plot in Fig. 2, extrapolated from the OECD statistics (OECD stat., 2021), shows the tremendous gap between Women and Men graduating in Engineering, Manufacturing and Construction in Japan.

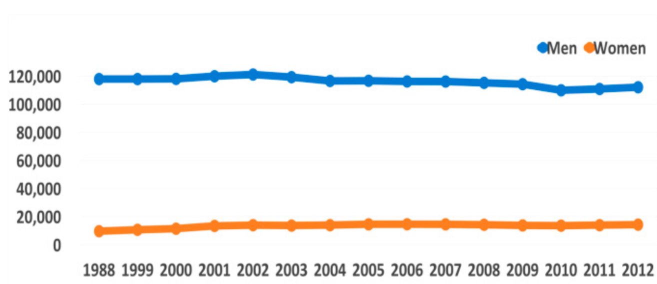

Fig. 2. Gender-specific graduate data in Engineering, Manufacturing, and Construction in Japan from 1988 to 2012. Image extrapolated from (OECD stat., 2021).

One of the stereotypes about women in Japan is that they are weak in science; however, according to figures calculated from the education ministry's fiscal 2018 Basic Survey of Schools, women's successful entrance exam ratio was better than men in all natural science faculties except medicine, as shown in Fig. 3.

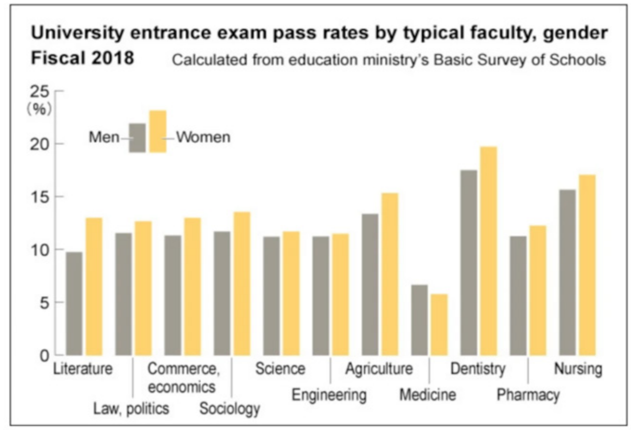

Fig. 3. Gender percentages vs University faculty type for entrance exam success rate in 2018. Image from (Kastuda, T., 2019).

The tradition of East Asian countries, including Japan, is characterized by the "Good Wife, Wise Mother" motto: women are taught to fulfill this role and live their lives conforming to this ideal. Although this ideal was asserted before World War II, it is still valid in this era. Reaching a gender-equal society while maintaining the country's strength in high-tech industries and basic science is fundamental for Japan, the fastest aging society in the OECD.

4. SOUTH KOREA

The inclusion of female personnel within STEM-related R&D in Korea has shifted in line with the development of R&D activities across the country, led by government-funded research institutes in the 1970s, industry in the 1980s, and universities in the 1990s. The rate of women enrolling in STEM higher education, specifically engineering, remained low in the 1970s, contributing to fewer women working in STEM-related corporate fields and participating in STEM R&D in the 1980s (Lee, E., 2001). The 1990s saw the emergence of more women enrolling and graduating in STEM fields, contributing to a greater number of female R&D personnel, as shown in Fig. 4 (Lee, E., 2001) (WISET, 2021).

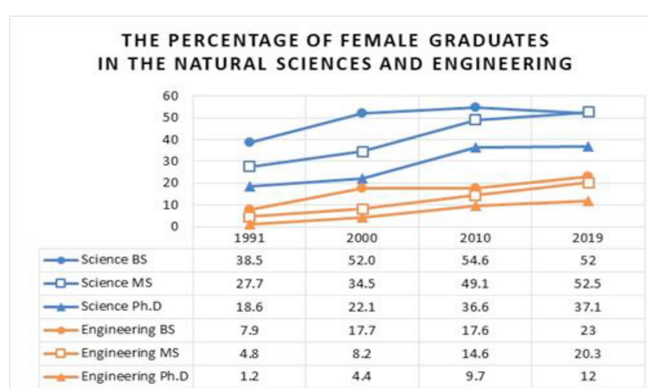

Fig. 4. The percentage of female graduates in the natural sciences and engineering.

Moreover, as the scale of university research grew throughout the 1990s, these universities played an important role in both training and hiring female scientists and engineers. Despite the number of women in STEM growing over time, the proportion of women undertaking engineering majors remains much lower, and plateaued around the 2010s, remaining fixed at around 20%. This trend can be attributed to persistent social preconceptions that women are not suited to engineering, which is evident in the fact that many women's universities in Korea do not offer engineering courses.

The employment rate of female students remains consistently lower than their male counterparts, with this gap widening as their educational level increases (WISET, 2021). The relationship between labor force participation and age is shown in Fig. 5. The employment gap between genders widens in the 30s and remains wide at older ages, indicating that women tend to leave their jobs to raise children and few return to their careers.

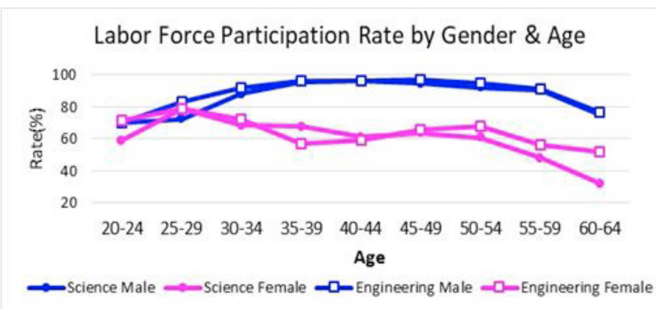

Fig. 5. Labor force participation rate by gender & age.

As of 2019, although the proportion of women in junior positions is improving, those in managerial or leadership positions remain at around 10%. The proportion of female project managers is not only lower than that of male counterparts, but the imbalance gets more serious (only 8.5%) in projects with budgets of more than $1 million (WISET, 2021).

Government policy supporting women in STEM began to shift in 1998 with President Kim Dae-Jung's women's policy, and the subsequent establishment of the Ministry of Gender Equality and the corresponding Act on the Prohibition and Relief of Gender Discrimination in 1999. These events marked a concerted effort to rebalance Korea's formerly heavily patriarchal society by promoting gender equality and penalizing gender discrimination in the workplace (Kim, S., 2005). In 2001, 25 government-funded STEM research institutes introduced a similar quota system, termed Recruitment Quotas for Women in STEM, following the government's recommendation. In December 2002, the Act on the Promotion and Support of Female Scientists and Engineers was enacted, which provided a legislative basis for this policy (Chung, H., 2014). This quota system mandates that the 107 participating public STEM institutes guarantee women a certain proportion of new hires each year, with the aim that the proportion of women in their workforces approaches 30%. As a result of these policies, the proportion of women in public research institutes has increased slowly but steadily, reaching 25.8% in 2019 (Chung, H., 2014).

According to the Global Gender Gap Report 2020 by the World Economy Forum (WEF, 2019), Korea ranked 108th in the 'Global Gender Gap Index' out of 153 countries surveyed, corresponding to 36th out of the 38 OECD countries. Korea also ranked 119th in 'Wage Equality' and 142nd in 'Legislators, Senior Officials and Managers.' These data suggest that policies to eliminate the glass ceiling and implicit gendered discrimination need to be more actively implemented within workplaces. On the other hand, these quota-based policies have spawned discontent among younger generations, who feel disenfranchised by perceived reverse discrimination and instead propose a merit-based employment system. As such, Korean STEM R&D institutes and, more broadly, the Korean government must work to prepare flexible policies that reflect the characteristics of each new generation of workers.

5. MALAYSIA

The success of women in STEM in Malaysia is rooted in the historical development of Southeast Asia. The historian Anthony Reid mentions in 1988 that one of the key tenets about South-east Asia as a region distinct from East and South Asia is the relatively high status of women; the relative autonomy and economic importance of women in the sixteenth and seventeenth century South-east Asia probably was higher than in any other part of the world (Reid, A., 1988a). Still, in the 1960s and early 1970s STEM related activities were largely male dominated and gender stereotyping was common. To overcome these issues, the government started a series of education plans to educate children without regard to gender, race or social background. From the 1970s onward, the government of Malaysia put a strong focus to motivate more students to choose STEM subjects. The goal of the 60:40 Policy was that 60% of all students major in STEM. This resulted in a significant number of Malaysians becoming proficient in the STEM fields. The focus on both genders and the establishment of dedicated girl's schools from the beginning of the STEM initiative resulted in 48.85% girls enrolled in STEM in 2014 (Khalid, S.M., 2018).

One important issue is the special support of the "Bumiputra" (affirmative action) by the government. The definition of Bumiputras is difficult as many groups are covered by that expression, but they can be roughly described as the old inhabitants of Malaysia before the immigration of Chinese, Indians and Europeans set in in the late 19th century. The vast majority of Bumiputras are Muslims. From the perspective of the empowerment of women in Malaysia this means that women with Bumiputra background have good access to jobs in the government sector – mainly administration and education. This results in a comparatively high number of women in top positions at universities in Malaysia.

Today the STEM strategy of Malaysia is becoming a success story. In most STEM sectors (except engineering) we see an almost equal higher education enrollment of female students. Enrollment data (Khalid, S.M., 2018) show women at 50.54% in science, mathematics and computer science and 38.72% in engineering, manufacturing and construction. In health and welfare, women's enrollment is almost 76%.

However, this perspective becomes more complicated in the context of the multi-racial composition of Malaysian society. While women in the Malay majority of the population find it easier to choose a career in STEM, the culture of modern Malaysian Chinese and Malaysian Indian communities are more closely tied to the traditional cultures of East and South Asia that were allegedly more patriarchal than those of South-east Asia (Hirschman, C. 2016).

An interesting and comprehensive article goes deep into the societal and psychological aspects of women engineers in Malaysia (Atiq, S.Z., et al., 2018); it cites an UNESCO report (2018) stating that women were almost 45% of the engineering workforce in Malaysia (academia and industry combined). Judging by the current data, Malaysia seems to be a success story compared with many other countries. It should be noted, however, that the trend of women's high enrollment in STEM disciplines is not yet reflected in the ranks of practicing engineers. According to a report from the Society of Women Engineers (SWE, 2021), although the number of registered women graduate engineers is trending up (from 25% in 2016 to 29% in 2019), women represented only about 8% of registered professional engineers in 2019.

6. DISCUSSION, CONCLUSION AND FUTURE WORK

The inclusion of women in the STEM fields is an ongoing process, triggered by the feminist revolution and facilitated by pioneering models of successful women who have chosen, despite the objections of the time, a scientific career. Despite some inherent differences between the societies/countries we presented in our previous paper (Chowdhury, F.N., et al., 2021), we identified many common elements of the process of including women in STEM fields, such as the similar period of time when the first notable cases of women appeared in the considered country, signaling the Zeitgeist (spirit of time), or, factors such as the need for technological labor force that has always encouraged the opening of technical fields to women. In the recent decades, the principle of diversity and inclusion has been embraced by many organizations, businesses, educational and other institutions around the world. Beyond the concept of diversity and inclusion, the practical need and desire to utilize the full workforce has inspired specific government policies in many countries; these policies encourage women's access to technical fields. The journey from principle or policies to implementation is ongoing, and as we see from the data, there is still a long way to go.

In the present paper, we are interested to assess the extent to which our observations remain valid if we fundamentally change the space where we explore the issues — so we chose four Asian countries. Although there is continuity with the previous work from the perspective of the criteria we use to study these communities, we have noticed some peculiarities with respect to each country.

Due to the lack of sufficient infrastructure, women in India are required to rely on family and / or society to become part of the STEM community, although it seems the value of STEM education is appreciated in general. In Japan, it was not until 1986 that women were recognized as part of the workforce, reflecting the size of the community-specific patriarchal system and its inflexibility. Due to the need for manpower for R&D, South Korea has managed to involve more women in STEM fields, although societal biases are reflected in the lack of STEM specializations offered by women's universities. An example that contradicts the previous ones is Malaysia, a country with a progressive history of gender equality, since the sixteenth and seventeenth centuries when women were socially better positioned compared to other parts of Asia. Maintaining the trend and assuming long-term economic development plans have resulted in high levels of gender parity in many STEM fields, at least in educational attainment.

To conclude, we clearly see how the labeling of STEM fields in the public narratives of a country influences women's access to this domain. Indeed, STEM fields are suggestive examples of how socio-cultural factors impact everything in communities and countries. We also see that economic development goals can help overcome traditional limitations in the presence of collective will. It can be hoped that barring any major systemic disruptions, if the current enrollment trends continue, the overall proportion of women in STEM fields should improve in the Asian countries that we explored in this paper. It should be noted, however, that simply increasing the numbers does not ensure women's participation at the highest levels of decision-making processes, and this leadership gap is not unique to STEM fields. This issue requires separate attention and analysis which will be the subject of our future work.

In future work, we plan to run a survey of literature on the topic of gender imbalance in STEM, particularly engineering. Over the last several decades, a large volume of published literature has been generated on this topic; papers from different communities --- STEM researchers, university and higher education administrators, business leaders, professional organizations, psychologists and sociologists, other stakeholders --- have addressed and analyzed this issue. There have been agreements, disagreements, debates, discussions. We plan to examine this literature to find patterns, opinions, recommendations, and best practices that can potentially help us in our quest for a more equitable and diverse STEM workspace globally

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