challenges

MDPI

Article

Investigating the Status of Women Engineers in Education and Employment during the COVID-19 Pandemic

Seema Singh

Department of Humanities, Delhi Technological University, Delhi 110042, India; prof.seemasinghdtu@gmail.com

Abstract: Engineering is traditionally considered a male domain with lower female participation despite various affirmative actions taken in recent decades. There is evidence of greater gender equality as a result of the COVID-19 pandemic and precautionary lockdown measures. With this in mind, this paper investigates whether women engineers in India were more adversely affected than their male counterparts by the COVID-19 pandemic. Such an impact may be explained by 'intersectional stigma', expanded upon in the literature on discrimination. The impact of such stigma varies in different countries based on socio-cultural factors. Through the use of ethnographic and statistical research methods on secondary and primary data from a sample of 384 engineers, this paper shows that the impact of COVID-19 is not significantly different between genders in engineering education and employment. This may be due to the high demand for digital engineering skills, and strong family support in Indian society. Engineering branch may play a relatively more important role than gender in terms of impact. This finding has repercussions for continuing engineering education (CEE) programs and regulatory bodies in India in terms of enhancing course content and the results may be used in developing affirmative programs in other regions.

Keywords: women engineer; placement; employment; COVID-19; engineering education

Citation: Singh, S. Investigating the Status of Women Engineers in Education and Employment during the COVID-19 Pandemic. *Challenges* **2022**, *13*, 27. https://doi.org/10.3390/challe13010027

Academic Editors: Satu Kalliola and Tuula Heiskanen

Received: 5 March 2022
Accepted: 8 June 2022
Published: 15 June 2022

1. Background

Industry 4.0 and the challenge to reach the UN's Sustainable Development Goals by 2030 have increased technical requirements in the production process of even non-technical sectors, which has brought engineers to the center of the development framework [1]. Diversity among engineers is also required to bring different perspectives on board. However, the engineering labor market is male dominated in most countries including India, despite various efforts to change this in the last thirty years, with some positive results. In 1991, women constituted merely 7% of total engineers enrolled in India, which increased to almost one-third in 2020 [2].

Early in 2020, the COVID-19 pandemic led to a precautionary complete lockdown by the Government of India on 25 March 2020, which continued to the end of May. Further, opening up from lockdown was implemented in a phased manner, causing disruption in the production process. As a result of the lockdown, the demand and supply of products and services drastically decreased, which led to a decrease in production levels [3]. This had a negative impact on employment, income, and well-being, and has resulted in mental distress for the workforce. Within the production system, special attention must be paid to women due to their dual responsibility and secondary role in the labor market. During times of economic downturn, the divide between women and men generally increases [4], as evidenced during the first year of the pandemic. Further, there is evidence of decreasing gender equality in general [5–10], and for women in Science, Technology, Engineering and Mathematics (STEM) in particular [11–14].

1.1. Impact of COVID-19 on Indian Women Workers

Women workers are employed in a wide spectrum of activities ranging from agriculture to urban micro-enterprises, as assistants in big enterprises to high-end workers as administrators. Even though the labor force participation rate for women is very low in India (less than 11%), 13.9% lost their jobs by April 2020 and 49% by November 2020. The female labor force participation rate (FLPR) among urban women fell to 7.35% (compared to 9.7% in 2019–2020). The rate continued to fall to 7.2% in October 2020 and 6.9% in November 2020. The FLPR among young women (in their early twenties) fell from 14.3% to 8.7% in a year. Based on past experience, it will take years before this damage is repaired if there are no more economic shocks. Recovery as a result of post-pandemic efforts has benefitted more men than women [4]. Women are feeling more exhausted, pressured to work, and burned out according to the McKinsey report on Women in the Workplace 2020 [15].

1.2. Impact of COVID-19 on Women Engineers and Scientists

Many studies on women in STEM worldwide have found more or less the same results. Women academic scientists in U.S. research institutions have experienced both positive and negative impacts of COVID-19, with the negative impacts outpacing the positive. A more concerning fact is the stark difference in negative impacts of COVID-19 by gender, rank and care work. Women researchers are significantly more likely than men to report inability to concentrate on research activities, particularly among those with children at home, resulting in less time for research as well as fewer grant submissions and publications during the pandemic [16]. Based on a sample of faculty across eight different countries including the United States in 2020, a study found that women scientists who have at least one child aged five years or younger were more likely than men to report that the pandemic led to a change in childcare routines that has reduced research time by approximately 20% [17]. A study conducted by the Australian Academy of Science between December 2020 and June 2021, with a focus on listening to the first-hand experiences of women in the Asia–Pacific STEM workforce, found that the COVID-19 pandemic has exacerbated pre-existing gender inequity across the Asia–Pacific region. A significant number of respondents reported a reduction in work productivity due to work-from-home arrangements during the lockdown. They mention that it has blurred the boundaries between the workplace and home as well increasing their domestic and caring responsibilities. Further, precarious and insecure work arrangements have reduced access to research facilities and workplaces [18]. Many editors of established scientific journals have indicated an overall increase in manuscript submission but most of them are authored by male researchers. In fact, a decrease was noted in the number of manuscripts submitted by women authors [19]. The Australian Academy of Science has suggested a regional collaboration along with supportive and understanding workplaces and communities to minimize gendered impacts of the pandemic on the STEM workforce [18]. The Organization for Women in Science for the Developing World (OWSD) conducted a survey involving its more than 5000 members between March and June 2020. Approximately two-thirds of members expressed that they could not travel to conferences or other important events. Women also reported interruptions to experiments or fieldwork (56%), teaching duties (31%) and course attendance (22%). Further, members experienced publication delays (20%), suspension of ongoing funding and difficulty in finding collaborators (17% each), lack of time to submit funding proposals (16%) or publications (14%), missing out on business opportunities or losing clients (13%) and being unable to take exams as scheduled (11%). Just less than 5% of respondents reported directly losing their job as a result of the pandemic. Due to increased domestic responsibilities, on average, 44% of respondents had to cut back on their working hours. More than half of respondents reported that childcare fell mostly to them including home schooling. However, there were some benefits, such as more flexible working hours (54%), expanding professional skills (42%), more time to work on research (27%), investing in new technologies for telework or tele-study (26%), broadening public engagement (20%) and augmenting scientific

publications (19%). Many members reported being involved in the pandemic response. Some of them were undertaking research on the coronavirus itself (4%) such as to develop treatments or vaccines, studying the impact of the coronavirus on other health conditions or its societal or economic impact (14%) [9]. In another 2020 study of faculty affected by the COVID-19 pandemic, researchers interviewed 80 academics who were mothers in the United States (25) and Italy (55). These women reported reductions in research productivity due, in part, to the need to devote more attention to teaching online courses, which was very difficult with small children at home. Both real-time and asynchronous online teaching were interrupted by children's demands, cries, or other background noise. Moreover, women reported a perceived cognitive deficit from managing the demands of children [20]. Another study on female employment (non-STEM) in Japan found that the employment rate of married women with children decreased by 4%, while that of those without children decreased by only 1%, implying that increased childcare responsibilities caused a sharp decline in employment among mothers. Further, mothers who left or lost their jobs appear to have left the labor force even several months after school reopening. In contrast to women, the employment rate of married men with children was not affected, which may have hindered progress in narrowing the gender gap in employment [5]. Time spent on domestic activities increased steadily during lockdown and mothers working from home were faced with difficult and conflicting roles, which put more pressure on women. Women who were unable to access social support continue experienced heightened levels of stress in their attempt to combine family caregiving and work, which ultimately affected their overall well-being [7]. Several affirmative actions were taken to improve gender equity, especially in STEM fields in recent years. The pandemic may be having a detrimental impact on women and may jeopardize gains made [21]. So, in a nutshell, there is a real risk of losing the progress made in terms of gender equity in STEM fields. With this in mind, this paper discusses the impact of COVID-19 on women in engineering education and employment in India during the third year for two reasons. First, this population was chosen because they are highly educated and skilled, at the high end of the labor force spectrum, and although female labor force participation in India is low and U shaped, as per the Periodic Labor Force Survey (PLFS), 2019–2020, the female labor force participation rate among women in engineering education and employment is very high (35%) [22]. They have digital skills through which they can interact and collaborate worldwide. The second reason relates to the Indian culture and the strong family bonds therein. How these women are dealing with these factors will be interesting to examine.

2. Theoretical Framework and Objective of This Study

Engineering is considered as related to machines which are both large and heavy. Engineering was first used to refer to military engineering, which may be among the reasons why engineering is seen as a male domain. The reproductive and productive roles of women and men are distinctly embedded in labor market participation. While professions such as doctors or nursing, which are related to care, love, and passion are seen as feminine, engineering is seen as sturdy, strong, mechanical and powerful, characteristics seen as masculine. So, women engineers may face 'intersectional stigma'. Goffman's seminal work of 1963 provides descriptions of the social processes of labels as well as social exclusion which lead to the development of such stigma [20]. The convergence of multiple stigmatized identities within a person jointly effect their labor market participation, health and well-being. While the historical and theoretical basis for intersectional stigma may be used for an enquiry of gender, there is little consensus on the following:

- How best to characterize and analyze intersectional stigma and/or
- How to design interventions to address this complex phenomenon—particularly in a cross-country analysis as the impact of such stigma may vary in different countries based on socio-cultural factors.

Nevertheless, it provides a useful framework to understand how various and overlapping factors of discrimination may impact an individual [14]. Researchers in economics,

sociology and political science have examined how characteristics such as sex, race, and health status affect the individual and society. The sociologist framework of stigma based on socio-cognitive approaches discusses the psychological impacts of these stigma and the processes through which these stigma (re)produce inequity [14,23]. This theoretical framework and the methodological implications of intersectionality theory are useful in understanding how the various and overlapping forces of discrimination may impact an individual [24]. With this in mind, the objective of this study is to investigate the following in light of COVID-19:

(i) Enrolment of women in engineering education,
(ii) Placement of graduate women engineers, and
(iii) Work and workplace experience of women engineers.

There are two hypotheses for the third objective

- H_{10} = positive impact of COVID-19 on women = positive impact of COVID-19 on men.
- H_{11} = positive impact of COVID-19 on women $\neq$ positive impact of COVID-19 on men.
- H_{20} = negative impact of COVID-19 on women = negative impact of COVID-19 on men.
- H_{21} = negative impact of COVID-19 on women $\neq$ negative impact of COVID-19 on men.

The findings of this study will provide insight into 'intersectional stigma' and give direction for designing programs/policies.

3. Materials and Methods

Both qualitative and quantitative research methods were used to analyze the research questions. First, two objectives were analyzed for pre- and post-COVID contexts in India. The third objective was discussed in light of the available literature for other countries and a comparison was made between male and female engineers. Steps taken for this study are as follows:

3.1. Descriptive Analysis of Secondary Data

All-India Council for Technical Education (AICTE) data are available on the AICTE dashboard and were used for descriptive analysis of enrolment and placement. Enrolment was analyzed by caste also. There is list of socially and educationally backward class population as scheduled class (SC), scheduled tribe (ST) and other backward caste (OBC) in the Constitution of India and the government may make any provision for the reservation for education and employment for them [25]. At present, there is quote for OBC, SC, and ST of the tune of 27%, 15% and 7.5%respectively in government education and employment [26].

3.2. Ethnographic Research

An ethnographic research method was used to understand and present the perceptions of women engineers on work and employment.

3.2.1. Participants Observation

Participant observation is a process used to learn about activities performed by research participants in their natural setting through observing them. It is very important to maintain a sense of objectivity through distance [27]. There is no unanimity among scholars and researchers about the standard procedure of participant observation [28]. Some researchers suggest that participant observation may be considered a supplementary method of data collection and tend to apply it together with interviews, group discussion and document analysis. They also accept participant observation as a flexible, methodologically plural and context-related strategy that may be integrated with various other methods [28].

In this study, participant observation was used to create a perspective and to decipher what is going on in the mind of the participants.

3.2.2. Unstructured Interview

Bernard (2011) discussed the following types of ethnographic interviews based on the level of structure and/or control of the investigator during the interview process:

(i) Less structured or ethnographer-controlled interviews—there is a total lack of structure or control and the ethnographer simply tries to remember and record conversations during the process [17].

(ii) Unstructured interviews are based on a clear plan that the researcher constantly keeps focusing on during the discussion and tries to navigate the discussion as per the objective of the study. At the same time, the researcher maintains minimum control over responses so that respondents may open up and express themselves in their own way. Such interviews may be used when the researcher has lots of time for conducting a long-term (classical) fieldwork and can divide the interview to many separate occasions. During unstructured interviews, both the researcher and the respondent know what is going on, without deception, and are aware that the discussion is more than "pleasant chitchat" [29].

(iii) The conventional format of descriptive interviews is similar to a natural conversation, and the ethnographer is just another participant [30]. As the author is a faculty member in a technological university, she has carried out both of the above-mentioned types of unstructured interviews several times in the last two years, in order to obtain perspective and to understand the psyche of engineering students and professionals.

3.3. Sample Size

It was decided that a sample of 384 engineers working and residing in India were required through the following formula for an unknown population [31].

$$\text{Sample Size} = (z^2 \times pq/e^2) \quad (1)$$

Here, e = the desired level of precision (i.e., the margin of error), p = the (estimated) proportion of the population which has the attribute in question, and q = 1 − p. The z value is found in a Z table.

Taking a confidence level of 95%, a z value of 1.96, and a margin of error (confidence level) of ±5%, the sample size required is:

$$\begin{aligned} &= ((1.96)^2 \times 0.5(0.5))/(0.05)^2 \\ &= (3.8416 \times 0.25)/0.0025 \\ &= 0.9604/0.0025 = 384.16 = 384 \end{aligned} \quad (2)$$

A Google form was generated for this paper. As there was limited time, known engineers were asked to fill the questionnaire and were asked to share the survey with their engineer friends. Along with introductory questions on age, marital status, engineering branch, etc., the Google form is having questions on positive and negative impacts of COVID-19. The last question was on bullying experienced by women engineers during the pandemic. Table 1 provides a gender and branch-wise profile of the sample.

As per the proportion of male to female enrollment at the national level in 2020–2021, almost 30% of respondents are female and the rest are male. All respondents are either from the corporate sector or start-ups.

Table 1. Gender and Branch-Wise Distribution of the Sample for This Study.

Branch	Male	Female	Total
Civil + Environmental Eng + Geo Engineering	53 + 0 + 0 = 53	20 + 1 + 1 = 22	73 + 1 + 1 = 75
Computer Eng + Information Technology + Software Engineering + Maths and Computing + Robotics System Eng	73 + 11 + 9 + 17 + 1 = 111	27 + 11 + 4 + 17 + 0 = 59	100 + 22 + 13 + 34 + 1 = 170
Electronics and Communication Eng + Electronics and Instrumentation + Electronic and Telecommunication Eng + Electronics and Computer	31 + 1 + 1 + 2 = 35	12 + 0 + 0 + 0 = 12	43 + 1 + 1 + 2 = 47
Electrical Eng + Electrical and Electronics Eng	14 + 4 = 18	8 + 1 = 9	22 + 5 = 27
Mechanical + Instrumentation and Control + Automobile + Production + Industrial Eng	27 + 5 + 8 + 3 + 1 = 44	4 + 1 + 1 + 0 + 0 = 6	31 + 6 + 9 + 3 + 1 = 50
Chemical + Petrolium Eng + Polymer Science and Chemivcal Technology	3 + 1 + 1 = 4	4 + 0 + 1 = 6	7 + 1 + 2 = 10
Bio-Technology + Engineering Physics	1 + 2 = 3	2 + 0 = 2	3 + 2 = 5
Total	269	115	384

3.4. Independent-Samples t-Test

An independent-samples *t*-Test is a statistical method to compare the means of two groups. The variance is assumed to be the same for both groups. The SPSS software was used for the tests. On the basis of the result of the Levene's test for homogeneity of variance, the first or second row has been considered.

3.5. Case Study

Yin identifies a case study as an 'empirical inquiry to investigate a contemporary phenomenon in real-life context, especially when the boundaries between phenomenon and context are not clearly evident' [29]. Stake (2005) adds that a qualitative case study often focuses on the experiential knowledge of a certain case which is closely related to social, political and economic influences. Moreover, to ascertain the credibility of a case study, descriptions and interpretations need to be made continuously during the period of the study [31]. The case study method involves a variety of interviews and an analysis of sites to acquire insights [31–33]. The respondent is also aware of the objective of the discussion. From the sample of 384 respondents, 52 women engineers agreed to further discussion on their professional life as well as their work–life balance during COVID-19, etc. Of the 52, 4 have children over 18 years old, 21 have children less than 18 years old and 27 are unmarried. Of the 21 women engineers who have children younger than 18 years old, 13 have two children and 8 have only one child. Three women engineers only have female children.

4. Analysis

Analyses were performed based on primary and secondary data.

4.1. Enrolment of Women in Engineering

It is clear from Figure 1 that there was a decrease in the enrolment of women in engineering in 2020–2021 from 2019–2020. Among the main reasons for such a decrease may be COVID-19, which has caused disruption in the economy and resulted in the loss of employment and earnings for many households. Consequently, COVID-19 has also resulted in dislocation and return migration for many households. In India, a daughter's engineering education is not seen as an expenditure but an investment because engineering

brides are more in demand in the marriage market. Traditionally, marriage is arranged by parents in India [34]. Further, the plus-two examination, a prerequisite to join graduate engineering programs, was delayed, which may have caused mental stress for students. Additionally, though there are provisions for educational loans from the commercial banks, the COVID-19 pandemic has adversely affected the financial health of the banking system as well and that channel may have also partially dried up or become critical in terms of their usual banking services [35].

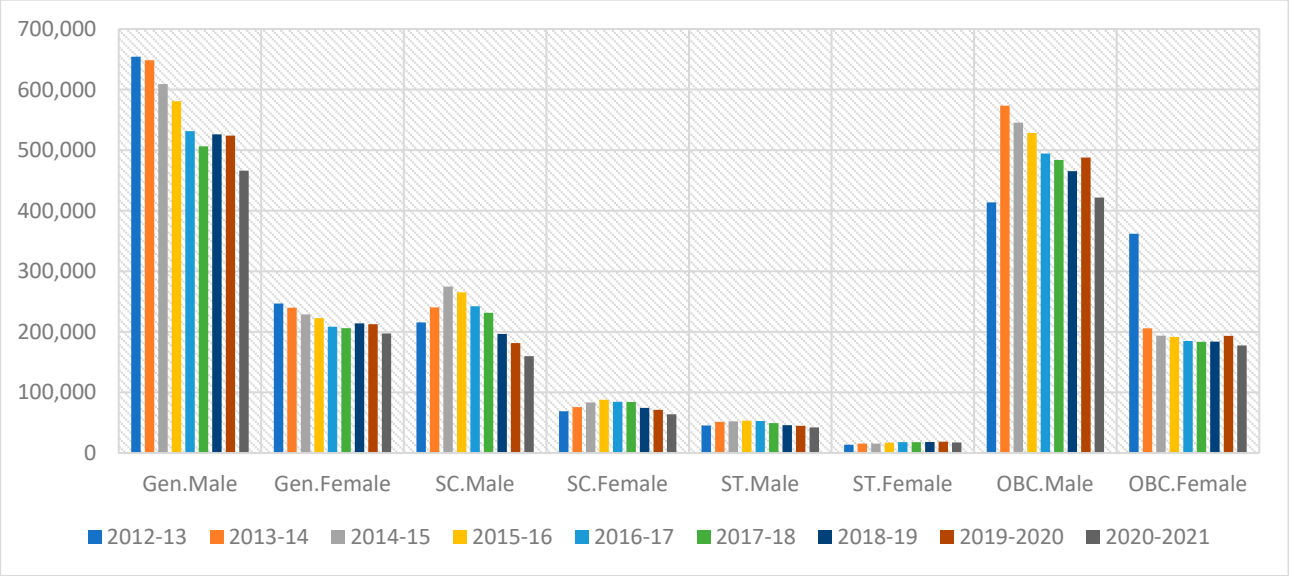

Figure 1. Caste-Wise Enrolment of Women in Engineering Education by Year. Note: OBC = other backward caste; SC = scheduled caste; ST = scheduled tribe. Source: [36].

When looking at the data up to 2019–2020, it is evident that the decline is not limited to the post-pandemic era but that there was a general decline in enrolment in the last decade for both genders (Figure 1), although at different rates. Though an investigation of the reasons for such a decline is beyond scope of this paper, reasons include the recession of 2008, the demonetization of the Indian economy in 2016 and the imposition of the Goods and Services Tax (GST), which have adversely impacted the market. Another reason may be Industry 4.0, where much of the repetitive or supervisory work will be performed by robots [1].

4.2. Internship and Placement of Women Engineers

As per the Indian engineering education system, industrial training is mandatory in the graduate curriculum. Companies recruit candidates into placements before completion of their degree programs. In October 2020, the Society for Women Engineers (SWE) conducted a survey of engineering students in India to understand how the COVID-19 pandemic was impacting their academics. While most students indicated that they had no intention of taking any time off from their studies, three-quarters expressed concern about delaying their graduation date due to the pandemic. Most were also concerned about the impact that this will have on their professional opportunities, such as the availability of internships [37]. There was not a significant decrease in placements from colleges and universities located in metropolitan areas but when the data were considered at the national level, a decrease of 19% was recorded (Table 2).

However, with the second year of the pandemic, the country has learned to survive and the economy has bounced back. During the second quarter (July–September) of the fiscal year of 2021–2022, the Indian gross domestic product (GDP) increased by 8.4% in contrast to a 7.4% contraction during 2020–2021 [38]. According to the figures issued by

the Union Ministry of Statistics and Program Implementation, the GDP at constant prices in the second quarter of 2021–2022 is estimated at USD 457.23 Billion, compared to USD 421.91 Billion lakh crore during the same period a year ago [39].

Table 2. Placement Data for Indian Engineering Institutions.

Year	Placement	Percentage Change from the Previous Year
2012–2013	559,625	---
2013–2014	613,105	109.5564
2014–2015	673,922	109.9195
2015–2016	701,506	104.0931
2016–2017	722,937	103.055
2017–2018	716,317	99.08429
2018–2019	795,624	111.0715
2019–2020	794,448	99.85219
2020–2021	648,436	81.62095

Source: [40].

The national-level data on placements for the current academic year are not available but lockdown has never been imposed throughout the country. The stakeholders of the Indian engineering education system have also gradually adjusted to the changed circumstances, popularly referred to as the 'new normal'. Opportunity for online education for entry, during and even continuing engineering education programs has increased. The online platforms were available even before the pandemic but were not used as much as they are now. The intensity of use has increased manifold. In a nutshell, digital innovation for different sectors of the economy is very much in demand and on the rise.

As most companies are opting to online modes for maximum productivity, there is bulk-hiring for students of computer and other related branches as these areas are in high demand. Almost 90% of the students of such branches (including female students) were already placed within two months of the placement period (2021–2022). However, they need to have the capacity to handle analytics, the ability to innovate and be capable of adapting to various sectors. Students, irrespective of their gender, are quite optimistic. According to the Centre for Monitoring the Indian Economy (CMIE), jobs for senior software engineers increased grown by 70%, while jobs for software engineers and for full stack developers have increased by 33% and 10%, respectively [41]. Though placement in traditional branches is slow, students in even these branches with the required knowledge on computer applications in relevant fields are in demand. The workplace is not going to be the same again. So, the onus is on the engineering education system to develop students for new workplaces and emerging market demand.

4.3. Work and Workplace Experience of Women Engineers during COVID-19

Women are not only studying engineering but also joining the labor market as graduate engineers. However, as they go up the hierarchical ladder, their number decreases due to conscious [1] and/or and unconscious biases [4]. In October 2020, a survey by the Society for Women Engineers (SWE) involving engineering professionals in India, aimed to understand how the COVID-19 pandemic was impacting their career plans. Among working professionals, there was general satisfaction with the way employers had responded to the pandemic and communicated about their efforts to address COVID-19 concerns among employees. Only 4% of employed respondents indicated that they were considering leaving the workforce. However, most men and women expressed concerns about losing their job and though concerns about the ability to find another job if needed were high across genders, women were more worried about their chances than men [37].

Almost a decade ago, 'work from home' was advocated and adopted as an affirmative action for the retention of women engineers in the labor market [35,42]. However, the same 'work from home' became unmanageable during the lockdown when travel was banned, even commuting for domestic help/maids and for food delivery systems such as Swiggy or Zomato. Women engineers and scientists have reported stress, being burned out and having no time for themselves. They have reported difficulty in managing both personal and professional duties. Women's opinions varied on how they integrate or segregate their work and non-work roles, acknowledging the difficulties they face in delineating work and non-work domains [3]. However, once travel was allowed again, senior members of families came to their rescue. Social help plays a crucial role in the professional growth of a woman [43]. As children's classes went online for children, children could attend classes from their grandparents' house. One of the respondents commuted everyday along with her husband and children to her parents' house, where her mother, who is herself a retired professor, took care of their kids, and prepared lunch and evening snacks so that the respondent and her husband could concentrate on their work. Another respondent sent her school-aged daughter to her parents' place in another city. Another respondent with a small kid hired full-time domestic help. She was happy even during lockdown as she was able to combine her work with monitoring the full-time domestic help.

Respondents were asked to give positive impacts of COVID-19 (Table 3). Responses included upskilling, opportunity to collaborate, more time from not needing to commuting, company growth being more than expected, working from home, more time to focus on themselves, and one respondent wrote that it taught him to live with limited resources. Engineers in digital branches also said that it was good for career and/or salary hike. In India, women's participation in the digital branches of engineering is very high.

Table 3. Difference between Male and Female Responses on Positive Effects of COVID-19.

	1 = Male 2 = Female	N	Mean	Std. Deviation	Std. Error Mean
Positive Effects of COVID-19	1	269	2.88	2.834	0.173
	2	115	2.43	2.128	0.198

An independent-samples *t*-Test was conducted on SPSS (IBM®, Armonk, NY, USA) for the third objective.

Levene's test for equality of variance F = 8.617 at Sig = 0.004, which is lower than 0.05. This means the variability in the two groups is significantly different and violates the assumption. However, SPSS also provides results after taking due measures which are shown in the second row. Here, the *t*-test for equality of means is 1.729 at Sig (2-tailed) = 0.085 (which is >0.05). There is no statistically significant difference between these two groups and the difference in means is by chance.

So, the result fails to reject the null hypothesis (H_{10}).

Respondents were also asked to give negative impacts of COVID-19 (Table 4). Responses include issues related to work–life balance, being burned out and tired, COVID-19 infection, losing loved ones, inability to concentrate/issues with mental health, lack of jobs, employment risk, career stagnation and lower increments in salary. Then, an independent-samples *t*-Test was run on SPSS to infer variations in the responses based on gender.

Table 4. Difference between Male and Female Responses on Negative Effects of COVID-19.

	1 = Male 2 = Female	N	Mean	Std. Deviation	Std. Error Mean
Negative Effect of COVID-19	1	269	2.74	3.128	0.191
	2	115	2.64	3.102	0.290

Levene's Test for equality of variance F = 0.425 at Sig = 0.515, which is greater than 0.05. This means there is equal variability between the two conditions assumed. Here, *t*-test for equality of means = 0.277 at Sig (2-tailed) = 0.782, which is greater than 0.05. Therefore, the differences between condition means are due to chance. So, the result fails to reject the null hypothesis (H_{20}) at 95% level of significance.

The integration of work life with personal life, family and paid support has worked as an opportunity as well. Blurring the line has resulted in increasing productivity as Brue 2019 has discussed in reference to women in leadership positions [35]. In fact, women engineers were working towards COVID-19 solutions [29]. Saving time not needing to get ready to go out or commute has increased time available for productivity including for upskilling or talking and negotiating for collaboration. There is no need to spend extra time obtaining VISAs, planning travel, etc., and no need to spend money for purchasing tickets for international travel, lodging, etc.

5. Discussion

The engineering workplace is male dominated and many women do not feel very comfortable in it, and hence they deviate from core engineering fields to other managerial positions or withdraw themselves from the labor market, which is ultimately a loss for the engineering sector [44]. Although the pandemic has impacted everyone, the impact was gender biased. Women were more adversely affected by the pandemic in India and elsewhere than their male counterparts. However, Indian women workers do not form a homogenous group but are part of a quite heterogeneous spectrum and women engineers are at the high end of it. Being from the same socio-cultural background, Indian woman engineers share similar concerns to other Indian working women, but these differ based on their income level and educational background. Compared with women engineers in other countries, however, Indian women engineers have the same economic and educational backgrounds (Figure 2).

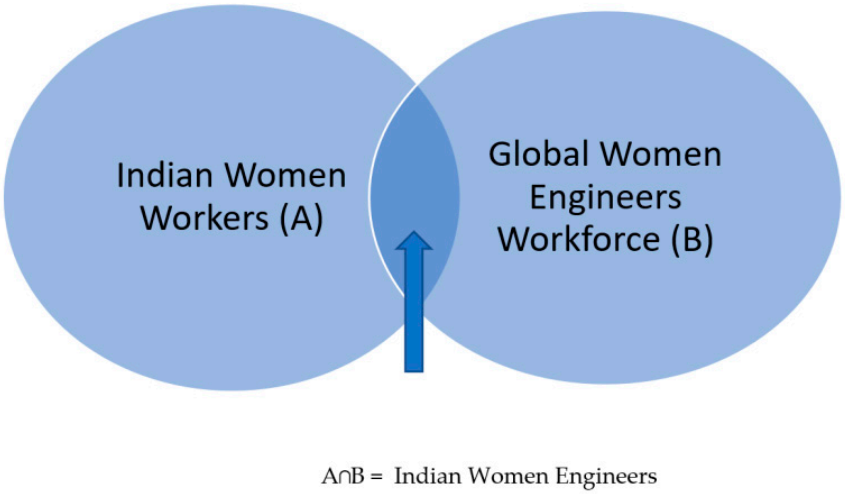

Figure 2. Indian Women Engineers.

There is a dual effect of COVID-19 on women engineers. Firstly, in times of economic downturn, the divide between women and men is bound to increase due to the well-established inequality increasing the pressures of a recession (15). Secondly, women are made to perform a disproportionately larger share of care work; as such, women engineers are also expected to do so.

As per the available literature, the pandemic has more adversely affected women workers. However, as per the present study, women engineers may not have been affected as much as other women workers in India. They report being satisfied with the way employers have managed the situation and while a very small section of them lost their

jobs, others obtained salary hikes. In fact, this variation is according to engineering branch. Women engineers were able to integrate their professional and personal lives due to the generous support from their families, which their international counterparts may not have. One of the respondents, a twenty-six-year-old entrepreneur, said that "lines of work life balance have gotten blurred. I'm not doing that well mentally and keep feeling burned out. Also lifestyle has gotten lethargic". However, she was happy with her professional growth. Another response, "My company is video based so it has been gaining growth faster than expected". One of the participants informed me that she was able to introspect more and pick up more healthy habits. A 60-year-old civil engineer who is a co-owner of a structural engineering firm said, "We learnt how to manage work through employees working from home from different parts of India". A 27-year-old electronics engineer working in a multinational company said she was happy to get a chance to collaborate internationally but is facing difficulty achieving work–life balance. With engineering knowledge and different perspectives, women engineers need to innovate to adjust within the 'new normal' workplace and they are capable of doing this, as three women engineers demonstrated by developing a remarkably accurate respiration monitoring device called 'rayloT' [45].

However, there is evidence of bullying experienced by Indian engineers in the literature [1,42]. Women engineers are subjected to emotional bullying at the workplace [1]. While physical and verbal bullying are bad, victims state that emotional bullying is worse, maybe due to destroying the self-confidence of victims [42,46]. Types of bullying experienced by women engineers include discrimination at time of joining, being given a greater workload, fault finding, being ignored during meetings, lack of promotion and lower salaries [1]. Although the survey in this study included a question on bullying, it was left blank by most respondents. Only 15% of the women wrote that they received lower salaries compared to male counterparts for the same work. In the discussion during case studies, most respondents said that though it is endemic to a certain degree, no new measures were introduced during the COVID-19 pandemic.

Stakeholders in the engineering sector, including regulatory bodies, scientific societies and employers, need to be more supportive by enhancing opportunities for enhancing skills and helping workers manage their work–life balance.

6. Conclusions, Suggestion and Limitation of This Study

The country-wide precautionary lockdown measures during the COVID-19 pandemic impacted growth adversely, thus eventually more adversely affecting the employment, income and well-being of women workers than their male counterparts as tends to happen in times of economic downturn, with the divide between women and men increasing due to the well-established inequality increasing the pressures of a recession [15]. However, women workers do not make a homogenous group. They are heterogeneous and the socio-economic forces of the labor market impact them differently. Women engineers are at the high end of the spectrum. The engineering labor market is also said to be male dominated and, as a result, many women engineers deviate or leave the labor market. This may be taken as an example of the convergence of intersectional stigma on women engineers in India due to which they have fared better than other female workers in the Indian economy and perhaps better than women engineers in countries where support from family members may not be as strong. An attempt was made to analyze intersectional stigma from the results of the independent-samples *t*-Test of a sample of 324 engineers and case studies of 52 woman engineers which clearly show that women engineers have performed on par with their male counterparts, with family and hired support. While there was some decline in the placement of graduate engineers in the first year, numbers have bounced back as the country deals with the pandemic. Companies are looking for more and more of a digital base for their production process. So almost 90% of students in the digital branches of engineering including women students were recruited within three months of the placement period. Regulatory bodies, scientific societies and employers need to enhance opportunities to enhance core digital skills and their application and help

workers manage their work–life balance. Bullying needs to be addressed in the working environment. However, the most important contribution of this paper is the analysis of intersectional stigma in terms of women engineers. The findings may be used as a reference for designing affirmative action towards increasing the number of women engineers. The snowball sampling method used for sample selection and responses being gathered using a Google form may be considered limitations of this study but obtaining responses from high-end workers in a small period of time is not easy.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Respondents were informed and consent was taken to use for the research purpose.

Data Availability Statement: Secondary data were open access and available online in anonymized form; therefore, no additional approval was necessary.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Singh, S. The fourth industrial revolution, women engineers and SDGs: An exploratory study with special reference to India. In Proceedings of the International Conference on Women in Science, Technology, Engineering and Mathematics (STEM), INWES-APNN19, Kathmandu, Nepal, 19–22 September 2019; WISE-Nepal: Kathmandu, Nepal, 2019.
2. Singh, S. Women in the engineering labour market in India. In Proceedings of the Panel discussion at APNN-2020, New Taipei City, Taiwan, 25 October 2020; TWiST: Taipei City, Taiwan, 2020.
3. The World Bank. Most Commodity Prices to Drop in 2020 as Coronavirus Depresses Demand and Disrupts Supply. 2020. Available online: https://www.worldbank.org/en/news/press-release/2020/04/23/most-commodity-prices-to-drop-in-2020-as-coronavirus-depresses-demand-and-disrupts-supply (accessed on 23 April 2020).
4. Vyas, M. Female Workforce Shrinks in Economic Shocks, Economic Outlook, Centre for Monitoring the Indian Economy. Available online: https://www.cmie.com/kommon/bin/sr.php?kall=warticle&dt=2020-12-14%2012:48:29&msec=703 (accessed on 11 December 2021).
5. Fukai, T.; Masato, I.; Daiji, K.; Shintaro, Y. COVID-19 and the Employment Gender Gap. Available online: https://ftp.iza.org/dp14711.pdf (accessed on 11 December 2021).
6. Fisher, A.N.; Ryan, M.K. Gender inequalities during COVID-19. *Group Process. Intergroup Relat.* **2021**, *24*, 237–245. [CrossRef]
7. Akuoko, P.B.; Aggrey, V.; Mengba, J.D. Mothering with a career during a pandemic; The case of the Ghanaian woman. *Gender Work Organ.* **2021**, *28*, 277–288. [CrossRef]
8. Reichelt, M.; Makovi, K.; Sargsyan, A. The impact of COVID-19 on gender inequality in the labor market and gender-role attitudes. *Eur. Soc.* **2020**, *23*, S228–S245. [CrossRef]
9. Ceron, M.; Zarra, A. A tale of two pandemics? COVID-19 and gendered policy responses in the EU. In *Cambio. Rivista Sulle Trasformazioni Sociali. OpenLab on COVID-19*; Elsevier: Amsterdam, The Netherlands, 2021. [CrossRef]
10. UN Women. COVID-19 and Violence against Women: What the Data Tells, 24 November 2021. Available online: https://www.unwomen.org/en/news-stories/feature-story/2021/11/covid-19-and-violence-against-women-what-the-data-tells-us (accessed on 11 December 2021).
11. National Academies of Sciences, Engineering, and Medicine. *The Impact of COVID-19 on the Careers of Women in Academic Sciences, Engineering, and Medicine*; The National Academies Press: Washington, DC, USA, 2021. [CrossRef]
12. Epperson, N.C.; Harry, E.; Regensteiner, J.; Ribera, A. The Impact of COVID-19 on the Mental Health of Women in STEMM. Available online: https://www.nap.edu/resource/26061/Epperson%20et%20al%20-%20FINAL.pdf (accessed on 20 December 2021).
13. THE. World University Ranking, Women in Science Are Battling both COVID-19 and the Patriarchy. 2020. Available online: https://www.timeshighereducation.com/blog/women-science-are-battling-both-covid-19-and-patriarchy (accessed on 20 December 2021).
14. Harvard, T.H. COVID-19 Scientific Response Marked by Sexism, Racism, Say Women Scientists, School of Public Health. Available online: https://www.hsph.harvard.edu/news/hsph-in-the-news/covid-19-scientific-response-marked-by-sexism-racism-say-women-scientists/ (accessed on 11 December 2021).
15. Johnson, T.P.; Feeney, M.K.; Jung, H.; Frandel, A.; Caldarulo, M.; Michalegko, L.; Islam, S.; Welch, E.W. Correction: COVID-19 and the academy: Opinions and experiences of university-based scientists in the USA. *Humanit. Soc. Sci. Commun.* **2021**, *8*, 278. [CrossRef] [PubMed]
16. McKinsey. COVID-19 Impact on Women Employment, Mckinsey's Company. Available online: https://www.mckinsey.com/featured-insights/diversity-and-inclusion/seven-charts-that-show-covid-19s-impact-on-womens-employment (accessed on 11 December 2021).

17. Fulweiler, R.W.; Davies, S.W.; Biddle, J.F.; Burgin, A.J.; Cooperdock, E.H.G.; Hanley, T.C.; Kenkel, C.D.; Marcarelli, A.M.; Matassa, C.M.; Mayo, T.L.; et al. Rebuild the Academy: Supporting academic mothers during COVID-19 and beyond. *PLoS Biol.* **2021**, *21*, e3001100. [CrossRef] [PubMed]
18. Australian Academy of Science. Impact of COVID-19 on Women in the STEM Workforce. 2021 | Asia-Pacific (Australian Academy of Science). Available online: https://www.science.org.au/supporting-science/diversity-and-inclusion/impact-covid-19-women-stem-workforce-asia-pacific (accessed on 18 December 2021).
19. Viglione, G. Are women publishing less during the pandemic? Here's what the data say. *Nature* **2020**, *581*, 365–366. [CrossRef] [PubMed]
20. Minello, A. The pandemic and the female academic. *Nature* **2020**, *ahead of print*. [CrossRef] [PubMed]
21. Kossek, E.E.; Allen, T.; Dumas, T.L. Boundaryless Work: The Impact of COVID-19 on Work-Life Boundary Management, Integration, and Gendered Divisions of Labour for Academic Women in STEMM, Report of the Ad Hoc Committee of the National Academies of Sciences, Engineering, and Medicine. Available online: https://www.nap.edu/resource/26061/Kossek%20et%20al%20-%20FINAL.pdf (accessed on 12 December 2021).
22. Nguyen, P.Q.; Soenksen, L.R.; Donghia, N.M.; Angenent-Mari, N.M.; de Puig, H.; Huang, A.; Lee, R.; Slomovic, S.; Galbersanini, T.; Lansberry, G.; et al. Wearable materials with embedded synthetic biology sensors for biomolecule detection. *Nat. Biotechnol.* **2021**, *39*, 1366–1374. [CrossRef] [PubMed]
23. Phelan, J.C.; Link, B.; Tehranifar, P. Social conditions as fundamental causes of health inequalities: Theory, evidence, and policy implications. *J. Health Soc. Behav.* **2010**, *51*, S28–S40. [CrossRef] [PubMed]
24. Jessica, C.H.; Lori, D.P. Un/Doing Intersectionality through Higher Education Research. *J. High. Educ.* **2018**, *90*, 347–372. [CrossRef]
25. Andrews, G.A. Reservation in India—Explained in Layman's Term's. Clear IAS. 2020. Available online: https://www.clearias.com/reservation-in-india/ (accessed on 2 May 2022).
26. GoI. Issue of Instruction on Reservation for the Scheduled Caste, Scheduled Tribes and Other Backward Classes in Services under the Government of India. 2010. Available online: https://documents.doptcirculars.nic.in/D2/D02adm/36011_6_2010-Estt.(Res).pdf (accessed on 2 May 2022).
27. Bernard, H.R. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, 2nd ed.; Alta Mira Press: Walnut Creek, CA, USA, 2005; Volume 6, p. 43.
28. Kawulich, B.B. Participant Observation as a Data Collection Method [81 paragraphs]. *Qual. Soc. Res.* **2015**, *6*, 43. [CrossRef]
29. Barnard, H.R. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, 5th ed.; Alta Mira Press: Lanham, MD, USA, 2011.
30. Whitehead, T.L. Introduction to the Cultural Ecology of Health & Change (the CEHC). CEHC Working Papers, TL Whitehead Associates. 2002. Available online: http://tonyIwhitehead.squarespace.com/toolsIproducts/ (accessed on 21 December 2021).
31. Yin, R.K. *Case Study Research, Design and Methods*, 3rd ed.; SAGE Publications: Thousand Oaks, CA, USA; London, UK; New Delhi, India, 2003; Volume 5.
32. Stake, R.E. Qualitative Case Studies. In *The Sage Handbook of Qualitative Research*, 3rd ed.; Denzin, N.K., Lincoln, Y.S., Eds.; SAGE Publications: Thousand Oaks, CA, USA; London, UK; New Delhi, India, 2005.
33. Suryani, A. Computing case study and Ethnography as Qualitative Research Approaches. *ILMU Komun.* **2008**, *5*, 127.
34. Singh, S. Are Women Engineers discriminated? In Proceedings of the Regional Conference of the International Network of Women in Science & Engineering (INWES), New Delhi, India, 12–13 October 2012.
35. Patel, A.; Debnath, N.C.; Mishra, A.K.; Jain, S. COVID-19-IBO: A COVID-19 Impact on Indian Banking Ontology Along with an Efficient Schema Matching Approach. *New Gener. Comput.* **2021**, *39*, 647–676. [CrossRef] [PubMed]
36. Turan, J.M.; Elafros, M.A.; Logie, C.H.; Banik, S.; Turan, B.; Crockett, K.B.; Pescosolido, B.; Murray, S.M. Challenges and opportunities in examining and addressing intersectional stigma and health. *BMC Med.* **2019**, *17*, 7. [CrossRef] [PubMed]
37. SWE. COVID-19 Research—India, 2020, Society for Women Engineers. Available online: https://swe.org/research/2020/covid-19-research-india/ (accessed on 20 December 2021).
38. Hindustan Times. India's GDP Grows 8.4% in Q2 2021–22, Compared to 7.4% Contraction a Year Ago. 25 November 2021. Available online: https://www.hindustantimes.com/business/indias-gdp-grows-8-4-in-q2-2021-22-compared-to-7-4-contraction-a-year-ago-101638275718292.html (accessed on 20 December 2021).
39. GoI. Estimates of Gross Domestic Product for the Second Quarter (July–September) of 2021–22, Ministry of Statistics & Programme Implementation, Government of India. Available online: https://pib.gov.in/PressReleasePage.aspx?PRID=1776500 (accessed on 11 December 2021).
40. AICTE. All India Council for Technical Education Dashboard. Available online: https://facilities.aicte-india.org/dashboard/pages/dashboardaicte.php (accessed on 17 December 2021).
41. CMIE. Demand for Non-Tech Job Roles Surge in 2021: Indeed, Economic Outlook, Centre for Monitoring the Indian Economy. Available online: https://www.cmie.com/kommon/bin/sr.php?kall=warticle&dt=20211223182027&msec=866 (accessed on 20 December 2021).
42. Singh, S.; Fanton, S. Women Engineers: A Comparative Study between India and Australia, 2014. *Int. J. Adv. Res. Technol.* **2014**, *3*, 108–122.
43. Brue, K.L. Work-Life Balance for Women in STEM, Leadership. *J. Leadersh. Educ.* **2019**, *18*, 32–45. [CrossRef]

44. Fouad, N.A.; Chang, W.-H.; Wan, M.; Singh, R. Women's reasons for leaving the engineering fields. *Front. Psychol.* **2017**, *8*, 875. [CrossRef] [PubMed]
45. OECD. Women at the Core of the Fight against COVID-19 Crisis, OECD Policy Response to Coronavirus. Available online: https://www.oecd.org/coronavirus/policy-responses/women-at-the-core-of-the-fight-against-covid-19-crisis-553a8269/ (accessed on 20 December 2021).
46. Sharma, A.N. Youth Employment and Unemployment in India: Issues and Challenges, Presidential Address. In Proceedings of the 62nd Labour Economics Conference, Roorkee, India, 11–13 April 2022.