Understanding barriers to female STEM students' adoption of online learning during a pandemic: An fsQCA analysis

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Abstract

The gender-gap in the fields of science, technology, engineering, and mathematics (STEM) is an impediment to the success of digitized education. The causal factors of this gap have remained a matter of speculation. This study focuses on the STEM gender gap in online learning, seeking to identify causal factors through an innovative fuzzy-set qualitative comparative analysis (fsQCA) that is integrated with sentiment analysis in the Asian context. Findings from the empirical results reveal two pathways to explain STEM gender inequality in the context of online classes. The study advances knowledge by providing insight into the causal factors that contribute to the existing gender gap and by disclosing what demotivates STEM female students in an e-learning environment. The findings will be helpful to practitioners seeking to address digital exclusion issues like the gender inequality in online learning platforms.

Keywords: STEM; gender inequality; online classes; pandemic, fsQCA

1. Introduction

Despite significant improvements in terms of female representation in the fields of science, technology, engineering, and mathematics (STEM) over recent years, men still greatly outnumber women within STEM education and related fields (Lee and Kray 2021). Interestingly, the effects of the Covid-19 pandemic on global society exposed significant gender disparities experienced by female STEM students within educational institutions. For example, a study conducted by STEM Women in 2020 reported that 60% of females STEM students had their careers halted as a direct result of the global pandemic. Similarly, a study conducted by Gupta et al., (2021) found many students actively chose to avoid courses that required computational thinking, practical or lab related work and mathematical problem-solving skills (such as those required within STEM education) during the Covid-19 crisis, as they considered these skills difficult to master within an online educational setting (Lu, H. et al. 2021). Significantly, previous research (Irawan, Dwisona et al., 2020; Garcia-Gonzalex, Torrano et al., 2020) has found that females who work or study within academia commonly face unique social, psychological, and normative constraints that further impede their online educational experience (Jarin, Mumu et. al., 2021). However, while previous research suggests that gender-stereotyping (Schonert-Reichl, Kitil et al., 2017), work-life balance (Mumu, Tahmid et. al., 2020), social capital, and technostress (Al-Furaih and Al-Awidi, 2021) are common factors that prevent women from pursuing a career within the STEM field, their impact on female participation within an educational environment remains unclear. Further, other key factors such as Internet habit, stress processing and mental health are currently unexplored within this context and thus remain a fruitful avenue to explore.

The primary aim of this paper is to increase understanding of the relational nature and impact of these key factors in relation to the female adoption of online learning platforms, through the following research questions:

1. Does the impact of gender-stereotyping and work-family negatively influence the adoption on online learning among female STEM students?
2. Does the impact of technostress and mental health conditions negatively influence the adoption of online learning among female STEM students?

3. Does the impact of Internet habit and stress processing negatively influence the adoption of online learning among female STEM students?
4. Does the impact of social capital negatively influence the adoption of online learning among female STEM students?

Methodologically, we apply fuzzy-set qualitative comparative analysis (fsQCA), to address these questions and test our hypotheses. fsQCA is a novel tool for examining causal relationships (Rihoux and Ragin 2008), providing multiple solutions that can explain the same outcome. The findings of fsQCA within this study offer multiple, distinct, and equally effective combinations of mental health problems, Internet habit, technostress, gender-stereotyping, work-life balance, and social capital problems, which explain high discouragement among female students towards continuing STEM education. Following on from this, a sentiment analysis was conducted to help us understand the feelings and emotions expressed by the sample. The findings of the sentiment analysis provide further support for the hypotheses in this study.

The contribution of this paper in the literature is threefold. Firstly, we extend the literature by exploring the relational nature and impact of stress processing and Internet habit, technostress and mental health, gender stereotyping and work-life balance and social capital problems on the adoption of online education by female STEM students. Secondly, we apply fsQCA to determine the causal relationship between female students in STEM and their discouragement towards online classes. Finally, sentiment analysis provides a deep insight into the emotions and feelings of the sample regarding gender inequality in relation to online education. The findings of this study provide strong empirical evidence that a combination of these research constructs negatively influence female students' adoption of online educational platforms. Identifying the interplay among the research constructs will help faculty members and practitioners to identify patterns that stimulate gender inequality, allowing them to create healthier academic environments that address the psychological problems related to work-life balance, gender-stereotyping and mental health.

The remainder of this paper is organized as follows. Section 2 examines existing literature and provides the theoretical motivation for the study. Section 3 builds upon section 2 to present the conceptual model and research hypotheses for this study. The research methods and design applied

in this study are detailed in Sections 4 and 5 of this paper. Section 6 presents a detailed overview of the findings of this study while section 7 provides a comprehensive discussion concerning the implications of the findings from this study. These implications are discussed in relation to the research hypotheses, their relevance to theory and practice. Study limitations and avenues for future research are discussed in section 8 of this paper.

2. Background

Perhaps somewhat unsurprisingly, the move to online and remote based learning that resulted from the Covid-19 pandemic, significantly impacted the work-life balance of students and academics around the globe, with researchers such as Kotini-Shah et al., (2022) citing increased workloads, stress and decreased self-care as key issues that need to be addressed. The cultural impediments experienced by Asian women (both generally and during the Covid-19 pandemic) further exasperates this issue (Carli, 2020). A key issue underlying this problem however is that gender equality within South Asia remains very much at an unsatisfactory level, with researchers Varma, R., Falk, J., & Dierking, L. (2022), reporting a strong underrepresentation of women in higher positions of academic and scientific institutions in South Asian countries. Similarly, Hasibun Naher, Tasfia Tanim, Nadira Sultana (2019) found that the gender distribution in student's enrolment in online learning shows an alarming gender inequality within Asian countries. Taking a feminist theory approach, we sought to highlight the voices of a population of female students who are facing issues in adopting online learning and have been underrepresented in online learning platforms (CohenMiller, A. et al., 2022).

While it can be argued that the Covid-19 pandemic opened the doors for global access to education, factors such as technostress, work-life balance, Internet habit and social capital have created significant barriers for many students; particularly within Asian countries. For example, a recent study conducted by Carli (2020) found that care-giving responsibilities of female students (for children or elderly relatives) made it difficult for them to balance family needs and work. The theory of planned behavior (TpB) suggests that intentions to adopt online learning, attitudes, subjective norms, and perceived behavioral control predict the likelihood that students will be more willing to adopt online learning. Significantly however, previous research has shown that high stress experienced by female STEM students has reduced their adoption of online learning

and educational platforms, an issue which has been exasperated by the global Covid-19 pandemic. Consequently, stress processing and gender inequality are key factors in this study. According to the social cognitive theory (SCT), personal attribution, environmental influencing factors (gender stereotyping and work-life balance) and intentional behaviors (Internet habit) will form a triangular relationship of interaction (Xu, P. et al., 2021). Thus, this study proposes that barriers to the adoption of online learning by female STEM students can be determined by a combination of cognitive factors in the form of technostress, mental health, social capital and stress processing. This study specifically investigates several causal factors that act as barriers to adoption of online learning amongst female STEM students during the Covid-19 pandemic.

3. Hypothesis Development

3.1 Technostress and Mental health:

"Technostress" is defined as a modern disease of adaptation caused by the inability of a person to cope with the new technologies healthily (Brod 1984). For Fischer and Riedl (2017), increased workloads, lack of a proper routine and increased sedentary screen time are key drivers of technostress – factors that were exasperated during the Covid-19 global epidemic. In fact, a recent study conducted by Mumu, Connolly et al., (2022) reported a significant increase of technostress amongst students engaging in online learning practices during the pandemic. Interestingly, there are many recent studies (Fischer and Riedl 2017, Christian, Purwanto et al. 2020, García-González, Torrano et al. 2020) which suggest that the online learning environment has effectively normalized technostress, triggering high stress levels, physical (musculoskeletal disorders, visual fatigue) and psychological disorders (burnout, anxiety, and depression), in addition to increased gender inequality and class absenteeism amongst students. Technostress can be significantly reduced however, if individuals choose to embrace the physical environment (going outdoors; socializing in person etc.) as opposed to spending long periods of time in front of their computer screens. However, in many Asian countries, female students - who are torn by family, peer and cultural pressures - are unable to embrace their physical environment to the same degree as male students. Moreover, a study conducted by Vitak, Crouse and LaRose (2011) found female students to be 'emotionally vulnerable' and more prone to psychological risk factors (such as technostress) as a result. Therefore, we hypothesize that:

H1: High Technostress among female STEM students reduces their adoption of online learning

3.2 Gender Stereotyping and Work-life Balance:

According to feminist theories, women tend to face more work-family conflict due to societal expectations (e.g., Family pressures), lack of gender equity, absence of empathy and lack of social support (Kray, Howland, Russell, & Jackman, 2017). For example, in Asian countries, female students are required to take care of their family, to help their mothers with household chores and look after siblings while doing online classes during the pandemic (Carli, 2020). According to social role theory and social structural theory, gender stereotypes develop from the gender division of labor that characterizes a society (Weiler 1988). Interestingly, gender stereotyping of masculine and feminine roles within academia is considered the most common form of gender bias in modern society (Kotini-Shah et al., 2022). Moreover, research conducted by Schonert-Reichl, Kitil et al. (2017) has found that gender stereotypes significantly influence the enrollment of women in STEM in many countries. For Bromberg, Techatassanasoontorn, & Andrade (2013), however, gender stereotyping is exasperated within Asian countries, with female students reporting less access to research resources and high incidents of drop out from education. Furthermore, the lack of apparent empathy and social support experienced by female Asian students can result in mental health issues, personality disorders and bipolar disorder (Oshio, Inoue, & Tsutsumi, 2017) Therefore, we hypothesize that:

H2: High gender-stereotyping and work-family conflict among female STEM students reduces their adoption of online learning

3.3 Stress processing and Internet habit:

Based on stress process theory (SPT), unequal positions in social hierarchies (e.g., gender equality in education) can predict differential exposure to stressors and affect mental well-being (Pearlin 1999). It is apparent that the Covid-19 pandemic had a detrimental impact on the mental health and work-life balance of female students (Gecaite-Stonciene, Saudargiene et al. 2021), forcing many to increase their Internet habit behaviours as a coping mechanism (Ho, S.C. et al., 2022). For example, researchers Su, Han et al., (2020) found females to be more vulnerable to social media addiction (SMA) then then their male counterparts, as they seek ways to overcome feelings of loneliness and strain. Increased levels of SMA and the high levels of stress experienced by female students can make it difficult for them to focus adequately on their education and careers

(Lissitsa and Chachashvili-Bolotin 2022; Yang, et. al., 2010). Thus, it is proposed that high levels of Internet habit can exert a significant negative effect on female students in relation to their adoption of STEM related online learning.

H3: High Internet habit among female STEM students reduces their adoption of online learning

3.4 Social Capital:

Within the literature, gender disparities are also related to women's lower social capital, ability to develop strong social networks and interpersonal relationships that provide privileges such as material resources, networks, and other benefits that support STEM career advancement (Ibarra 1993). Studies have shown (Casad, Franks et al., 2021; Alruwaili and Ku, 2019) that lower social capital can have a negative impact on how students engage with their peers, academics, and faculties, with female students struggling to form relationships and reporting higher levels of social isolation in comparison to male students. Furthermore, female students in STEM also reported a lack of formal mentoring in online classes, limited opportunities to collaborate on research projects due to work-family conflict, and feelings of isolation in the virtual classroom (Casad, Franks et al. 2021). In comparison, a study conducted by Handel, Stephan et al., (2020) reported that male students did not experience any significant issues in terms of research collaboration or forming relationship with their faculties within the online environment. Therefore, we hypothesize that:

H4: Lower social capital among female STEM students reduces their adoption of online learning

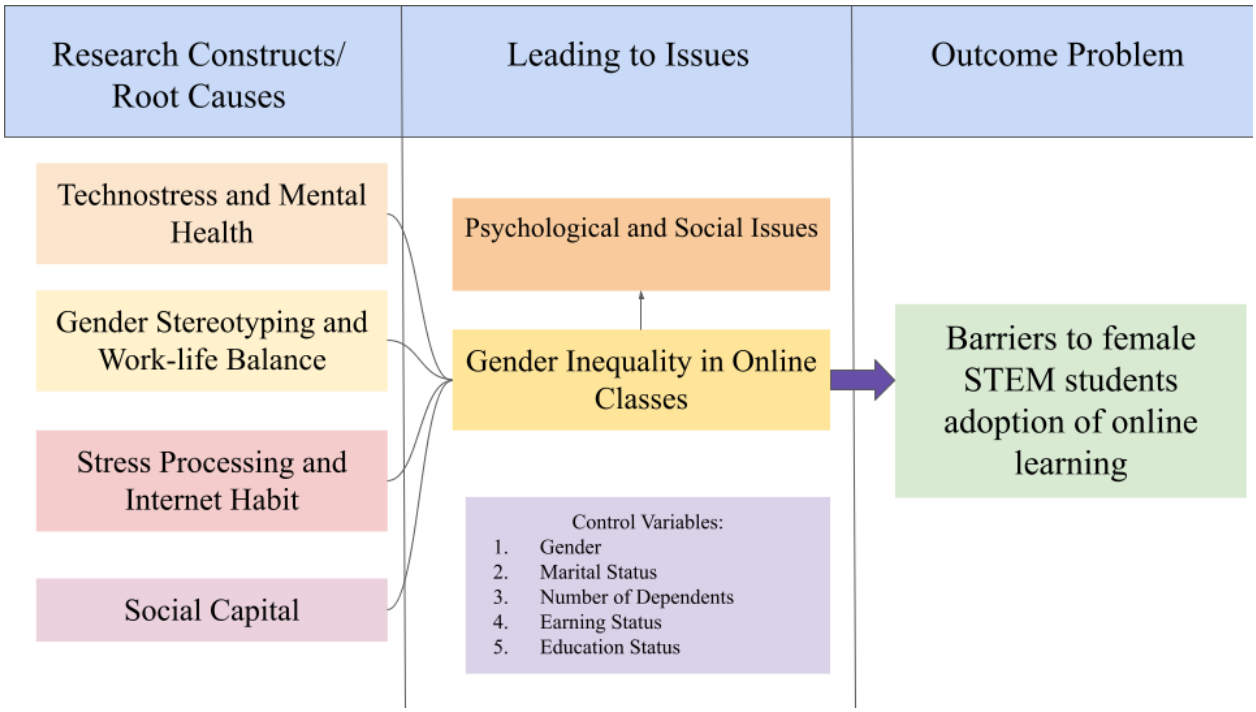

Figure 1. Conceptual model explaining the barriers to adoption of online learning among female STEM students

4. Method

Due to lockdown restrictions, an online survey was distributed using a snowball sampling technique in this study. The survey was conducted in the summer 2021 (April-May). The respondents were predominantly students (undergraduates and graduates) from STEM backgrounds in Asian countries. The participants answered the survey questions based on self-evaluations, outlining their views and suggestions on gender inequality and the ways in which to minimize it. Participants who were in school or from non-STEM backgrounds were removed from the sample. The questionnaire consisted of questions using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). 139 responses (all university students) were recorded. 4 responses were discarded due to incomplete data, resulting in a final sample of 135 responses (90 percent of the initial sample). The final sample consisted of 26.70 percent male students and 73.30 percent female students. 68.75 percent of the students were from India and Bangladesh with the remaining 31.25 percent of the students representing South Korea, Malaysia, Pakistan, and Sri-Lanka. Finally, the sample is diverse in terms of education status, earning status and marital status.

Next, two steps were followed to evaluate the research constructs for reliability and internal consistency: The Cronbach's alpha result shows that there is support for construct reliability as all the values are higher than 0.7, so it is evident that the instrument used for the data collection instrument is a good fit for continuing fsQCA. Next, the Stata software was used to perform a correlation analysis with the results showing that there is a limited relationship between the constructs (all variables are within the cut-off threshold of <0.6). The variance inflation factor (VIF) was also run for every variable with the results showing that the VIF for every variable is below 3 – thus multicollinearity is not an issue (O'Brien 2007). This provides sufficient support for the research model proposed.

Variables	Mean	SD	α	(1)	(2)	(3)	(4)	(5)
LagBehind (1)	3.575758	1.732597	0.8435	1.000				
TechnoStress (2)	3.212121	1.615503	0.8804	0.569	1.000			
WorkBalance (3)	3.515152	1.641669	0.8476	0.716	0.649	1.000		
InternetHabit (4)	3.242424	1.581738	0.9059	0.472	0.333	0.516	1.000	
SocialCapital (5)	3.363636	1.557606	0.8267	0.943	0.676	0.743	0.533	1.000

Table 1. Descriptive Statistics and Correlation Analysis of research constructs

5. Analysis

This study applies fsQCA which is known for integrating the fuzzy sets with the QCA (Rihoux and Ragin 2008). Use of fsQCA within this study allowed us to keep the number of causal conditions 'minimum' without omitting variable biases like regression models. In addition to engaging in additional qualitative exploration fsQCA also uses both qualitative and quantitative assessments that create a bridge between qualitative and quantitative methods. The fsQCA mainly offers two types of configurations. These are created using both the necessary and sufficient conditions to provide several solutions explaining the same outcome depending on the presence, absence, or on a do not care condition (i.e., either present or absent) of the configurations. The necessary and sufficient conditions are important since it helps differentiate between the core and peripheral conditions. The core ones are the strong conditions needed for the outcome and the peripheral ones are the weak conditions needed for the outcome.

5.1 Necessity Analysis:

To identify if any of the causal conditions is a necessary condition for the presence i.e. to explain why the female STEM students are lagging in adopting online learning - an analysis of necessity is performed for both the presence and absence of the condition. From a set-theoretic approach, necessity suggests that a condition is a "superset of the outcome", thus for each case in the provided sample, the fuzzy-set membership score of the outcome is smaller than the fuzzy-set membership score of the causal conditions (Ragin 2006). Also, for a condition to be necessary, the consistency should always exceed the threshold of 0.9 (Schneider and Wagemann 2010). For conducting the analysis of necessity, the dedicated function in fsQCA software 3.0 is used that calculates both the consistency and coverage scores for each causal condition as well as their negated values. As all the consistencies lie between 0.39 to 0.75, analysis for data calibration of the full non-set membership can be continued.

Constructs	Consistency	Coverage
TECH	0.737079	0.851948
~TECH	0.398876	0.483636
WORK	0.683146	0.903448
~WORK	0.428090	0.253333
INT	0.532584	0.844560
~INT	0.483146	0.459854
SOCI	0.687640	0.972906
~SOCI	0.430337	0.228346

Table 2. Necessity analysis of the research constructs

5.2 Data calibration:

There are mainly two methods that researchers apply for data calibration in QCA. The first one is the direct method where the three thresholds need to be defined, which are full membership, full non-membership, and the cross-over point that represents the level that a case belongs to a set (Ragu-Nathan, Tarafdar et al. 2008). The second one is the indirect method where the measurements require rescaling based on qualitative assessments and the researcher's in-depth knowledge regarding the cases. Although either method can be applied based on the underlying theory and the nature of the cases, for this study we applied the direct method. The three thresholds are based on the 5-point Likert scale from the research questionnaire. The calibration process was

carried out where 1 denoted the full membership, 0.50 denoted the crossover point, and 0 denoted the full non-membership (Rihoux and Ragin 2008). Finally, all the values were calibrated on a logistic function to fit into the three thresholds.

In this study the calibration process shown below was used in the fsQCA software 3.0 to convert the scale into continuous fuzzy sets (direct method): Calibrate (x, n1, n2, n3) where x denotes the research construct to be transformed, n1 denotes the full membership range set to 4, n2 denotes the crossover point set to 3, and n3 denotes the full non-membership set to 2. The computational formula for the constructs is given below:

compute: OUTLAG = calibrate(lagbehindoutcome,4,3,2)

compute: TECH = calibrate(technostress,4,3,2)

compute: WORK = calibrate(genderworklife,4,3,2)

compute: INT = calibrate(internethabit,4,3,2)

compute: SOCI = calibrate(socialcapital,4,3,2)

5.3 Generating the truth table:

In this step, the fsQCA software 3.0 is used to generate a truth table with the newly computed calibrated data. The truth table generates 2k rows where k equals the number of conditions, and each row of the truth table shows each possible combination for the conditions provided. For example, if there are 3 conditions, the truth table will provide 8 possible logical combinations among them. After generating the truth table, cut-off values of frequency and consistency are set. A frequency cut-off point is important to ensure that a minimum number of empirical observations is obtained. For small and medium-sized samples (less than 150 cases), the cut-off point for frequency is 1, however for large-scale samples (more than 150 cases), the cutoff point must be set >1 (Rihoux and Ragin 2008). As the number of cases in this study is 36, the frequency cut-off point is set at "1". A low consistency threshold might lead to errors, allowing false-positive conditions (Dul 2016). Thus, a relatively high consistency threshold is set at >.90, which is a standard metric for fuzzy-set analysis.

TECH	WORK	INT	SOCI	Number of cases	OUTLAG	Raw consist.	PRI consist.	SYM consist
0	1	1	1	1	1	0.988372	0.987342	0.987342
1	1	1	1	8	1	0.961373	0.96	0.96
1	1	0	1	3	1	0.926829	0.922414	0.922414
0	1	1	0	1	0	0.637931	0.5	0.5
1	0	0	0	1	0	0.363636	0.282051	0.282051
1	0	1	0	1	0	0.363636	0.282051	0.282051
0	0	0	0	6	0	0.124088	0.097744	0.0977444

Table 3. Truth Table after logical minimization

6. Results

6.1 fsQCA analysis:

Our fsQCA analysis shows 2 pathways explaining the barriers to adoption of online learning among female STEM students. The basic assumptions are tabulated in table 4. The analysis includes set-theoretic consistency values for each of the configurations as well as for the overall solution with all values being above the threshold (>0.9). The consistency of the configuration measures the degree that a subset relationship has been approximated, and the coverage assesses the empirical relevance of a consistent subset (Rihoux and Ragin 2008). The overall solution coverage indicates the extent that high intentions can be determined based on the configurations identified and is comparable to the R-square value (Pappas, Mikalef et al. 2019). An overall solution coverage of 0.795506 suggests that the two solutions obtained from the fuzzy analysis cover a substantial proportion of the outcomes.

Solution Set	Causal Recipe	Raw Unique Coverage	Coverage	Consistency
Solution 1	SOCI*INT*WORK	0.606742	0.103371	0.964286
Solution 2	SOCI*WORK*TECH	0.692135	0.188764	0.971609

***solution coverage: 0.795506

***solution consistency: 0.972527

Table 4. The configurations explaining the barriers to adoption of online learning among female STEM students

For determining the causal recipe towards gender inequality and why female students are lagging in adopting online learning, solution sets 1 and 2 present combinations for which the different

factors may be present or absent depending on how they combine with each other. The fuzzy membership among groups is identified focusing on natural sets based on demographic information and behavioral traits of the students. These different solution sets help us to find multiple pathways to interpret the reasons behind gender inequality that demotivates female STEM students to adopt online learning. The results depict that the solution sets confirm H2. Thus, we can validate that high gender-stereotyping and work-family conflict among female STEM students reduces their adoption of online learning. Although solution set 2 confirms H1, we fail to reject it for solution set 1. Similarly, for solution set 1 we reject H3 but for solution set 2 we fail to reject H3. Finally, we accept H4 for solution set 2 and reject it for solution set 1. Such variations in the solution sets provide interesting viewpoints based on control variables like gender, education status, earning status, marital status and number of dependents. The solution sets are explained in the following sections.

Solution 1:

This represents a special group of female students whose marital status is single, are unemployed and care for more than one dependent. The results suggest that high gender-stereotyping, work-life balance problems, high social capital problems, low stress processing and Internet habits negatively affect female STEM students' adoption of online education. These findings are significant as they highlight the importance of gender-stereotyping problems and social capital issues in this regard. In addition, the absence of male students within this solution set provides much scope for future research studies (i.e., gender stereotypes among students towards masculinity and femininity).

Solution 2:

This represents a small portion of male and female students whose marital status is married, are employed and care for more than one dependent. The results suggest that high gender-stereotyping, issues of work-life balance, high technostress and low social capital problems negatively affect female STEM students' adoption of online education. These findings are significant as they emphasis the relationship between technostress and online education.

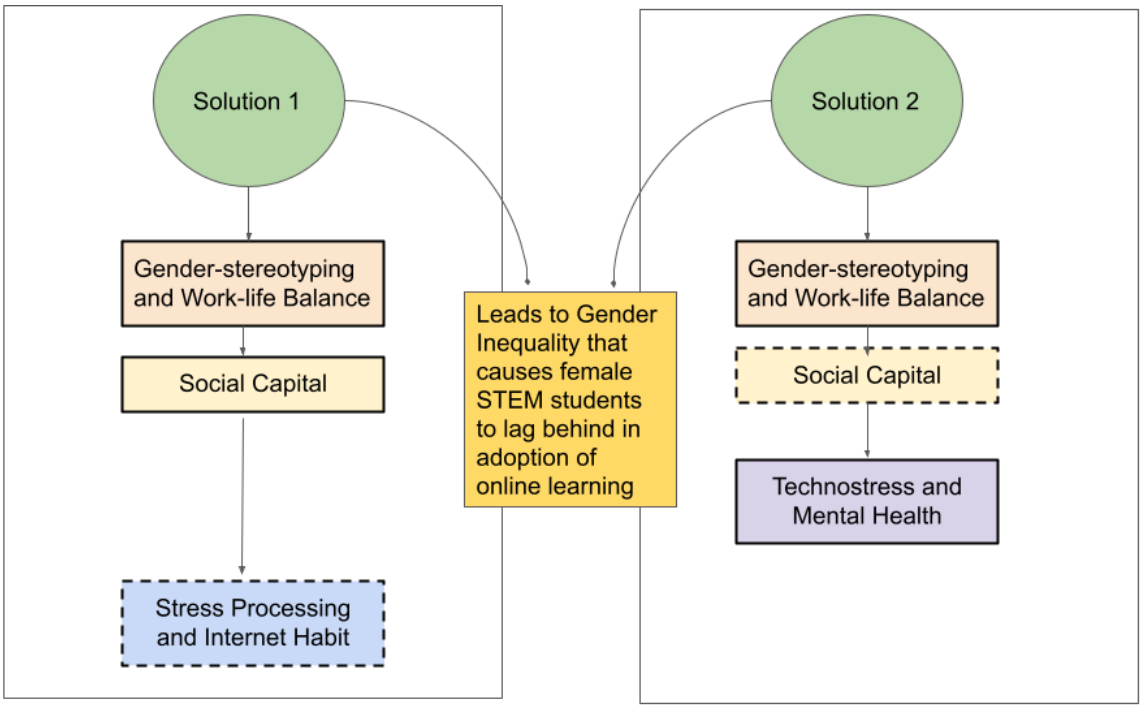

Figure 2. Visual presentation of the configurational pathways to explain the barriers to adoption of online learning among female STEM students (the arrows represent a sequence; lined boxes explain the presence of the variables; dotted boxes explain both presence and absence of the variables; and no box explains the absence of the variables)

6.2 Sentiment Analysis:

A sentiment analysis was conducted to extract the emotions of female STEM students regarding the barriers they face in the adoption of online education. Several key emotional triggers relating to gender inequality were identified in this study. For example, for 83% of females in solution set 1, expressed negative sentiment towards gender inequality and further noted that gender stereotypes impeded their adoption of online learning. Similarly for 58% of females in solution set 2, increased screen time, lack of appropriate ICT knowledge and increasing technological developments had a negative impact on their mental health, thus explaining their failure to adequately adopt online learning platforms.

The findings of our sentiment analysis were strongly supportive of the fsQCA results of this study, providing strong evidence that gender stereotyping, social capital and technostress negatively impact female adoption of online education in this study

Sentiments	Response	Percentage
Positive	08	29.63
Negative	19	70.37
Total Sentiments	27	100

Table 5. The sentiment analysis of female STEM students

7. Discussion and Implications

The current study identifies several key factors relating to gender inequality in the adoption of STEM online learning. As noted in section 6 above, the findings of the sentiment analysis were strongly supportive of the fsQCA results, suggesting that gender stereotypes and social capital negatively impact women's higher studies choices. They suggest that a greater level of gender-stereotyping as well as work-family conflict increase the mental health stresses experienced by Asian female students, which has the effect of reducing their adoption of online learning, thereby confirming H2. Furthermore, the findings provide evidence that lower social capital problems restrict female students from participating spontaneously in virtual classes and therefore reduce the likelihood of their adoption of online learning, thereby confirming H4. Both outcomes are clearly evident in the participants' responses. For instance, participant X32 wrote "On many occasions, women may underestimate their chances of enrolling into a selective university and may shy away from chances of top universities because of the competitive environment of the assignment process". Many also agreed that they use social media, such as Facebook, Instagram, and Twitter too much as a coping mechanism to deal with the stress of a longer working hour system. This may also cause a low attention span towards STEM education.

Drawing from the results of fsQCA, it is apparent that social capital intervenes in all paths without being a core condition as both its presence and absence impede the technology adoption among female STEM students in online classes. For example, longer working hours as well as increased responsibilities at both home and work were found to have a demotivating effect on 67% of the sample in this study. As noted by participant X64 "Sometimes, faculty members take a long class at night that causes technostress. In most cases, our female batchmates cannot even attend them, and I think it is because their families don't allow them, or they just feel awkward to do classes at

that hour". Therefore, such barriers to online learning can seriously demotivate female STEM students to stay focused in their career trajectories.

The findings from the proposed solution support that multiple combinations of sufficient and necessary conditions exist that explain why adoption of online learning is reduced among female STEM students. The findings of the fsQCA analysis support H2 as high levels of gender stereotyping and work-life balance problems are important causes as the barriers in adoption of online learning. Similarly, the analyses reject H3 as high levels of Internet habit and stress processing are not important for most of the solutions. For H1 and H4, we see their validity is mostly depended on the control variables (gender, marital status, earning status).

Previous literature has shown that high levels of technostress and gender-stereotyping are the important barriers in adoption of online learning which is consistent with our fsQCA findings (Al-Furaih and Al-Awidi, 2021). However, while gender-stereotyping was an important factor in our study, the results suggest that high levels of technostress may not act as a strong barrier in the adoption of online education. Moreover, our results suggest that high levels of Internet habit and stress processing does not play a significant role as a barrier for online learning adoption among female STEM students, which is not consistent with previous literature. Therefore, these findings offer new insights to the technology adoption and digital exclusion literature. These findings advance our knowledge by showing that issues such as technostress, Internet habit and stress processing are insignificant barriers that underpin the existing gender gap in relation to female STEM students' adoption of online learning during the pandemic.

The implications of this paper are three-fold. *Firstly,* this study explored the key factors relating to gender inequality in relation to online learning platforms, to better understand the barriers that are impacting female STEM students' adoption of online educational platforms, thus contributing to pedagogy, technology adoption and digital exclusion literature. The study identified several causal factors, that if addressed will help academicians and practitioners to bridge the gender diversity gap within academia.

Secondly, this study combined the three unique theory perspectives (Theory of Planned Behaviour; Feminist Theory and Social Cognitive Theory) to offer new and exciting theoretical insights into the digital exclusion of female STEM students in relation to their online learning and educational practices.

Finally, the study findings of this study provide actionable evidence-based insights for academic faculty members seeking to promote a gender-equal academic environment that supports female students more effectively. For example, increased social supports and flexibility in class scheduling could reduce the effect of gender stereotyping and facilitate female students' attendance and active participation in online education. The development of appropriate policies and procedures that seek to regulate gender equality within Asian society should also be considered. For example, a significant lack of parental learning support and low levels of access to technical resources have sadly denied a large number of female students from gaining an education in many Asian countries (UNESCO and UNICEF, 2021; Van de Wetering, R., 2021). Significant policy reform could help reduce the work-life dilemma experienced by many Asian female students, allowing them to engage fully with online educational and STEM related opportunities presented to them.

8. Conclusions

Drawing on fsQCA and sentiment analysis, this study empirically examines the combination of conditions that determine barriers to online education among female STEM students during COVID-19. fsQCA analysis identified two key pathways affecting female STEM students' adoption of online educational platforms. Sentiment analysis provided strong support for fsQCA providing highly valuable information that would not have been obtained if the study had been conducted using a fsQCA approach only. These combined findings advance empirical and practical understanding of the pathways, which result in female students lagging their male counterparts in adoption of online learning particularly in STEM fields.

As is the case with all research, this study contains several limitations. For example, the methodology of this study was limited to QCA and sentiment analysis. While the use of QCA and sentiment analysis brings a new angle to gender inequality within STEM research, future studies

can employ more quantitative methods to examine this phenomenon. Secondly, as the study is limited to constructs identified from extant research, future research should explore the configuration of other conditions that are not captured specifically in this study. Lastly, this study collects data using survey questionnaires of student opinions. Therefore, future studies are advised to utilize longitudinal or panel data to further increase reliability and validity of the study findings.

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