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Girls' lower STEM career aspirations Across Different Countries: A Case-Specific Analysis- USA, Germany, Saudi Arabia, and Mexico

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Abstract

In most of the countries, women have made immense improvement in educational attainment and labor market participation in recent decades. However, they are still under-represented in science, technology, engineering, and math (STEM) education and subsequent careers. The most plausible way to explain women's lower-representation in STEM is to investigate the career expectations of 15- years old adolescents who are going through challenges as they start tracking future majors and careers. Thus, it is crucial to understand which factors influence their career goals to address the gender gap in STEM. Prior studies primarily concentrated on either performance- based explanation or the influence of psychological factors (self-efficacy) in influencing STEM career aspirations, overlooking the mediation roles of self-efficacy. This investigation tackles this gap by exploring whether self-efficacy in math can mediate the gender gap in STEM-aspirations after controlling for academic performances and parental socioeconomic status across four nations—the United States, Germany, Saudi Arabia, and Mexico. Utilizing data from the 2022 Program for International Student Assessment, this research applies logistic regression with AMEs and Fairlie Decomposition to identify the mediation effects of math self-efficacy on STEM aspirations. The results show that whereas gender disparities in math self-efficacy influence girls' lower STEM goals, wider-ranging structural and cultural elements are also significant.

Keywords: Gender gap, STEM career aspirations, self-efficacy, logistic regression, Fairlie Decomposition

1. Introduction

Studies reveal that women are surpassing men in educational attainment (Breen et al., 2010; DiPrete and Buchmann, 2013), particularly in OECD countries young women are reported to attain more advanced qualifications than men (OECD 2024, 2017). However, gender differences in subject selection in STEM (Science, Technology, Engineering and Mathematics) vs. non-STEM are still persistent (Bradley, 2000; Hägglund & Leuze, 2021). Moreover, young women's underrepresentation in STEM domain has become a universal trend (Ceci, Williams, & Barnett, 2009). Women tend to overrepresented in subjects, such as- Education (78%), Health and welfare (76%), Social sciences, journalism and information (64%) and Arts and humanities (63%), while men lean to STEM subjects- such as in Natural sciences, mathematics and statistics 50%, in Engineering 76%, ICT 81%). This horizontal gender segregation in education further influences to professions (OECD, 2017), supports income inequalities between genders as STEM education leads to better career and higher earnings (Charles 2017; OECD, 2017), and restrict innovation and scientific advancement (Anker, 1997).

Women's underrepresentation in math intensive fields contribute to gender inequality in labor market (Beede et. al., 2011; Perez-Felkner &. Thomas, 2017; Kahn & Ginther, 2017; Weinberger, 1999), particularly in countries who claim to be gender equal (Charles & Bradley, 2002; Breda et al., 2020). Despite educational achievement, women's labor market outcomes (wages and career growth) are still limited (Anker, 1997; 1998). This inconsistency suggests that higher degrees alone cannot mitigate the gender gaps in job opportunities and benefits. Beyond work life, this gap emerges also in student life when they start career planning (Anker, 1998). Paradoxically occupational segregation is more visible in Scandinavian countries than in Asian contexts, which explains why maximum working sectors in several developed countries either highly male- or female- dominated. Furthermore, women prefer to study and work in biology, medicine, and agriculture, while men concentrate on mathematics, and engineering (Xie & Shauman, 2003).

'What predicts STEM career aspirations of students'- is one of the mostly studied themes in education research, yet significant gaps persist in understanding association between STEM aspirations and individual factors across different cultural and socioeconomic contexts. Nevertheless, a lingering question keeps coming up: why do girls, despite performing equal or even better than boys, show less interest in STEM professions? Though education systems (Ertl., 2004) and labor markets (Hägglund & Leuze, 2021) clearly impact gendered aspirations, individual factors like higher parental socioeconomic status (Lloyd et al., 2018), and academic achievement (Cheng et al., 2021) can also predict the gap in STEM aspirations. A crucial component of this question is self-efficacy, refers to believing in your ability to handle anything thoroughly, directly connected to STEM career aspirations (Wang & Degol, 2013) and is affected by gender stereotypes (e.g., 'math is for boys'; Makarova et. al., 2019; Breda et al., 2020).

In adolescence (at age 15) students embark on making more specific career objectives when they start picking subjects to specialize in, however, their future career goals are still in the initial phase and can be easily influenced by social pressures (Anker, 1998). On the other hand, if the study investigates older cohorts, it risks analyzing careers already shaped by gender stereotypes. Moreover, if it explores students of other ages, analysis will fail to understand the situation and challenges 15 years old students feel as they start taking their future seriously. Thus, before they start college or enter into the work force, it is crucial to understand how society and other factors influence their career goals to address the gender gap in STEM. For these reasons adolescence (age 15) is a crucial age to study.

The gender-equality paradox—where girls in wealthier and gender- equal countries like the USA and Germany shows less interest in STEM despite having freedom to determine their professional route and equal access to education than the less gender-equal countries like Saudi Arabia and Mexico (Stoet & Geary, 2018; Charles 2011; Charles & Bradley 2009), in which STEM outcomes and engagement primarily depends on policy interventions (Babineau, 2023), and socioeconomic conditions (Chavatzia, 2017; OECD 2022). This phenomenon further encourages cross-national analysis.

This thesis covers a few significant study gaps by investigating how self-efficacy in math predicts STEM career choices across diverse cultural aspects after controlling academic performance, coupled with parental socioeconomic status (SES). As previous literatures have solely explored math self- efficacy as determinant of STEM desires, fewer studies have been conducted on the critical connection of mediation path (gender → math efficacy →STEM aspirations). Moreover, this study will compare the STEM aspirations in different cultural settings other than Europe and USA. As these countries (USA, Germany, Saudi Arabia and Mexico) cover distinct stages of education systems, financial growth, and social norms around gender and STEM education, they can offer a fascinating analytical angle. Applying PISA data 2022, this study offers a cross-national, case- oriented analysis that explores the mediation role of math efficacy in determining STEM career goals.

2. Literature Review

Despite significant advancements in gender equality and access to education, girls' engagement in STEM-related study and careers consistent to be low than those of boy's and this gap becomes a global trend (Stoet & Geary, 2018). This gap shaped by several factors, including intrapersonal factor (Self-efficacy; Erdmann et. al., 2023; Eccles & Wigfield, 2020), socioeconomic influences (Eccles & Wigfield, 2020), sociocultural norms (Leuze and Helbig, 2015) and institutional features (Hägglund and Leuze, 2021; Blasko et al., 2018; Hillmert, 2015). To better understand, this section examines both theoretical and empirical research from interdisciplinary academic fields. The key focus of this section are three individual-level factors that influence girls' aspirations in STEM (academic performance, parental socioeconomic status, and self-efficacy). However, before delving more into empirical research it is essential to know- what occupational aspirations are? Occupational aspiration is the only profession that a person identifies as the most suitable option at any given time (Gottfredson, 1981)-have emerged during adolescence by two-way socialization-

- Social Cognitive Career Theory implies self-efficacy impacts career aspiration by influencing a person's confidence in his competence to pursue and persistent in a particular field (Lent et al.,1994).
- Expectancy-value theory suggests aspirations are reflections of predicted possibility of achievement and consistency of cultural norms. For example, female' lower self-efficacy in math and science and perceived depreciation of math and science as 'masculine' field are crucial in influencing gender gap in career aspiration (Wigfield & Eccles, 2000).

These conceptual models highlight how gender norms unfairly deter females from following STEM careers, regardless of their academic performance.

2.1 Individual Predictors

Academic achievement, specifically in subjects like math and science, can significantly predict STEM aspirations. Academic performance is significant; however, as a determinant of STEM aspirations it is unable to entirely explain gender gap in STEM aspirations. Cheng et al. (2021), concludes that Boys with strong performances in math and science courses tend to consider STEM careers (e.g., engineering), on the other hand girls, although performing highly, typically opt for professions in biology and medicine or in non-STEM (e.g., Appendix E). As a consequence, girls choose fields that are socially accepted and typically known as feminine fields, like healthcare or education (Charles & Bradley, 2009; Stoet & Geary, 2018).

Similarly, the role of parental SES cannot be ignored. The gaps in social resources and educational opportunities have an adverse effect on STEM desires and ultimately raise gaps in STEM disciplines. Correspondingly, Lloyd et al. (2018) argue that parental education (as a proxy of parental SES) and gender influence student's intentions for work in STEM fields. Students (particularly girls) with higher educated parents are more inclined to favor STEM occupations primarily because their parents can support them with resources, experiences, encouragement and guidance (Chavatzia, 2017; Lloyd et al., 2018). Nevertheless, girls are less driven to pursue STEM than boys notwithstanding family support. PISA 2018 (OECD, 2020) uncovered interesting information that higher socioeconomic background students were more likely to select highly paid STEM careers like engineering and scientists than their colleagues from lower socioeconomic backgrounds. On the other hand, students from poorer socioeconomic families were probably going to select alternative occupations than conventional STEM ones. The study suggests that socioeconomic levels influence job aspiration independent of academic performance. Lack of resources discourages girls from low-income families from pursuing STEM professions (Blasko et al., 2021, Hamilton & Hamilton, 2006), whereas girls from high-SES backgrounds take advantage of resources and opportunities and opt for STEM careers (Blasko et al., 2021).

Self-efficacy refers to an individual's trust in his skill to perform particular tasks to achieve success (Bandura, 1997). It is trusting one's ability to execute required steps to gain specific results and often denote as task-specific self-confidence (Artino, 2012). So, academics have depended on the idea of self-efficacy to determine and explain human behaviors including academic achievement (Artino, 2010). Self-efficacy in math impact educational outcomes and career aspirations (Larson et al., 2015). Girls' belief in their capabilities in math can determine their decision in enrollment in these courses in future (Simpkins et. al., 2006). Emprical studies suggest that girl tend to report lower self-efficacy in math and science compared to boys, even when their academic performance is identical (Huang, 2013; Wang & Degol, 2017; Blasko et al., 2021; Zhang et al., 2022), leading to fewer girls choosing STEM careers (Blasko et al., 2021).These findings indicating a possible mediating roles of math self-efficacy in the gender disparities in STEM aspirations depicted in Figure 1- an association the present study directly examines-

Hypothesis 1: Girls are less likely than boys to choose STEM jobs since they have low math efficacy.

Figure 1: Mediation paths in explaining STEM expectations.

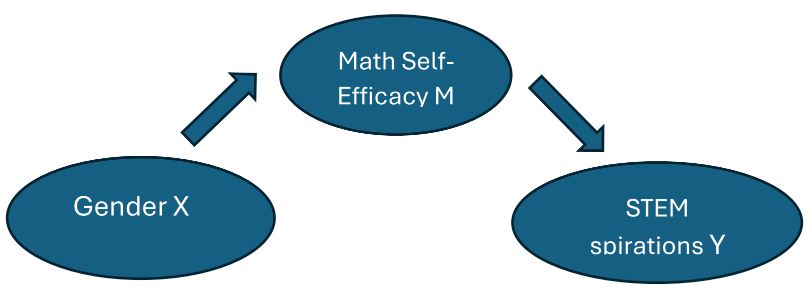


Figure 1 shows that mediating role of math efficacy can explain STEM aspirations. Scholars consistently suggested the effects of self-efficacy in influencing decision to follow STEM careers and emphasized the influence on girls predominantly (Brown et al., 2016; Lent et al., 2016). This gap is widened by gendered expectation, where STEM subjects are often portrayed as masculine that discourage girls from pursuing related career (Miller et al., 2015). These findings recommend that improving self-efficacy increases the likelihood of STEM careers among girls and can shrink the gender gaps in STEM.

2.2 Gender Stereotypes and Education System

Interestingly, the gender-equality paradox provides an unexpected perspective of analyzing cross national difference to STEM gender gaps. Blasko et al. (2021) revealed that despite being an egalitarian country- such as USA and Germany, gender perception on who 'belongs' to STEM pose an effect on both boys' and girls' expectations for STEM careers, eventually contributing to gender-based segregation in work. Moreover, in these countries gendered preconceptions regarding math and science being non-feminine disciplines- such as portraying scientist as male (Miller et al., 2018), may significantly weaken females' self-efficacy. Furthermore, Germany's vocational education and training (VET) system also reinforce this paradox. Germany's early tracking in education system sort adolescents into academic and vocational career paths, driving girls into culturally "feminine" career like nursing or caregiving (Hamilton, 1999). Once sorted, changing tracks become harder and this inflexibility influences gendered expectations from a young age (Hamilton, 1999; Ertl, 20004). In the USA, though the education system is more comprehensive with less formal sorting, girls still refrain from pursue STEM since they concern of being judged as "unfeminine" (Cheryan et al., 2015). It denounces cultural stereotype about STEM is not for girls (Miller et al., 2015). Similar to USA, educational sorting system is less segregated in Saudi Arabia and Mexico.

Nevertheless, prevalent cultural stereotypes, early marriage and household responsibilities, and workplace challenges such as insufficient caregiving alternatives and ongoing discrimination—restrict women's shift from education to STEM employment (22% employment) (Babineau, 2023). Moreover, socioeconomic inequalities in Mexico reinforce the gender gap as girls have limited access to STEM infrastructure, trained teachers and resources (UNESCO, 2019). As result, merely 9% female students opt for STEM degrees in Mexico (UNESCO, 2019). These contrast scenarios of these four countries suggest how gender gap in STEM career aspirations may vary by country, especially in those countries where gender equality persists with social prejudices. Moreover, country context- including gender norms, education systems, labor market participation may impact the mediating role of self- efficacy. These perceptions arouse the H2 and H3 while supporting the main theme of gender-equality paradox.

Hypothesis 2: The gender gap in STEM career aspirations is stronger in countries with higher gender-equality (Germany, USA) compared to countries with lower gender-equality (Saudi Arabia, Mexico).

Hypothesis 3: The mediating role of math self-efficacy differs across the USA, Germany, Saudi Arabia, and Mexico

3. Data, Variables, and Methods

3.1 Data

This study utilizes data from the Programme for International Student Assessment (PISA) 2022, the international education survey to test hypotheses. PISA assessments are conducted every 3 years to measure the knowledge and skills of 15-year-old students in mathematics, science, and reading. And in each circle, one of these majors is examined. Mathematics was the main focus of the PISA 2022 cycle, with additional assessments in reading, science, and creative thinking as minor areas. The 2022 cycle also included financial literacy assessment of young people as optional for countries and economies. A total of 690,000 students, representing about 29 million globally from 81 countries, participate in the assessment of 2022. This study uses 23,884 students from USA, Germany, Mexico and Saudi Arabia. All the assessed students are between the age of 15 years and 3 months and 16 years and 2 months and enrolled in grade 7 or higher. Student sampling weights applied for ensuring representative data for each nation with coverage index more than 80% except Mexico (64%). In most countries, data collection consists of 2 hours long computer-based adaptive tests and background questionnaires lasting 35 minutes (For students and additional surveys for principals, teachers, and parents in selected countries). The same test material was used in each country. Furthermore, PISA applied a two stage stratified sampling design, including carefully selected school based on stratification standards and randomly selected 35 students from each school (PISA, 2022).

3.2 Variables

The dependent variable is if a student expects to work in a STEM occupation. To measure the occupational expectations, students had to respond to an open-ended question: "What kind of job do you expect to have when you are about 30 years old?" The career expectations were coded by PISA using ISCO-08 (the International Standard Classification of Occupations 2008). STEM occupations are defined as expected to work across all the ISCO08 sub-major categories of science, engineering and information and communications technology professionals (coded as 1) (see online Appendix A for a list of occupations). Students who expect to work in other fields (51%) and students who don't expect to work in STEM- vague or undecided responded (12%) are identified as non-STEM occupations (recoded as 0) accounted for 63% of the population. Life science professionals and associate professionals (technicians) are excluded from the STEM career as gender gap in these professions has decreased over the decades as women tend to entry more in life science professionals (Mann & DiPrete, 2013). These classifications followed the PISA 2022 framework as well as McDaniel (2016) and Hägglund & Leuze's (2021) STEM definition. Moderate to high percentage (15% to 36%) of missing data found for STEM career expectations across countries. Moreover, Germany has the highest percentage of missing values for STEM expectations (see Appendix C), and non-response answer of students is solely responsible for this missingness. This study coded skipped questions, no response, and invalid responses (smiley face, etc.) as Stata's native missing as .m, .i, .n and followed OECD (2019) guidelines to treat no-response ('9999') as missing data (.k). If the study includes ‘no-response’ reply in non-STEM, the percentage of overall missing data will slump, and it might arouse measurement inaccuracy and misclassification bias since these non-responding students might choose STEM studies in future and enter STEM careers.

As per PISA's framework, self-efficacy is a stronger predictor of career choices for students than academic performance (OECD, 2019). To test the hypothesis, this study employs the mathematics self-efficacy index, which measures students' confidence in solving math problems. Responses were scaled to a standardized metric (mean = 0). Missingness in mathematics self-efficacy is 9% to 22% and Germany has the highest percentages of missing values. Some countries discourage students from confidently self-reporting their abilities as their education and culture focuses on precision and self-criticism. Countries where students have the best average performance, often self-report their skills negatively (Sanchez & Dunning, 2023). 48% German students think creativity cannot be changed (OECD, 2023- Factsheets Germany), representing their strict self-views and self-criticality that overpower their confidence. Another reason for skipping answering can be avoid being boastful and arrogant due to ambiguous phrasing in questions (OECD, 2023). However, underdeveloped metacognitive skills to evaluate their aptitudes cannot be ignored as well. Additionally, after 2 hours of cognitive tests, students might feel exhausted responding to self-efficacy questions and skipping them (OECD, 2023).

To adjust the effects of academic performance on STEM job expectations, this thesis considered proficiency in mathematics, science, and reading as control variables. PISA measures student proficiency in mathematics, science, and reading through plausible values (PVs), which are multiple imputed performance estimates obtained from Item Response Theory models. Rather than a single-point estimate, these plausible values represent a range of possible competency levels for each student and account for measurement errors (PISA 2023). For the sake of simplicity and computational effectiveness, this study employs the initial plausible value (PV1MATH, PV1SCIE, and PV1READ) for each subject while acknowledging the OECD recommendations of utilizing all ten PVs.

This study further controls parental socioeconomic status (SES). Parental education predicts educational resources, home learning environments, and academic mentorship that influence career aspirations (Blasko et al., 2021). For this reason, this study utilizes parental education as a standardized proxy for SES. Parental education is a categorical variable and is measured using the highest educational attainment of either parent. Missingness in parental education is less than 5% except Germany (16.84%). The Appendix C presents a percentage of missingness by country. Gender is a binary variable (Male/Female). The USA, Germany, Mexico, and Saudi Arabia have been chosen this study. PISA applies final student weights, which account for the stratified, clustered sampling design to produce unbiased population estimates. The weight of each student indicates their accurate representation in the national population of 15-year-old students. To ensure true representation in subgroups, all models apply weighted analyses.

3.3 Methods

This study incorporates statistical approaches to investigate variations in STEM career interests between boys and girls in selected four countries and whether math self-efficacy helps explain these gaps. It also examines whether the gender gap is higher in more gender equal societies. The first section of the analysis relies on descriptive statistics to understand primary variables such as parental education, academic performance, and math self-efficacy across those 4 countries. These values show cross-country variation in math-efficacy and socioeconomic backgrounds and how they vary by gender, which contribute to guide for deeper analysis.

Next, two-stage logistic regression with average marginal effects (AMEs) are used to evaluate if the gender gap remains after accounting for performance, math efficacy, and socioeconomic status (parental education). Baseline models **(logit (STEM Aspiration) = $\beta_0 + \beta_1$(Female))** isolate the raw gender gap while full Models with controls **(logit (STEM Aspiration) = $\beta_0 + \beta_1$(Female) + β_2(Mathefficacy) + β_3(mathperformance) + β_4(scienceperformance) +β_5(readingperformance) + β_6(PrentalEducation))** measure mediation effects of variables. These models were chosen since they demonstrate results in percentage points changes (e.g., how much more likely boys are to choose STEM than girls), making findings straightforward to interpret and apply to policy. Corresponding Breda & Napp (2019), this study applied Fairlie Decomposition to justify the approach of non-liner decomposition for logistic models (Fairlie, 2005; 1999). Fairlie Decomposition separates the effects of each variable to the STEM gap. Considering the statistical correlations between academic scores and math self-efficacy, multicollinearity test has been applied. The study generated the variance inflation factors (VIF) for the predictors for all four countries. Finally, missing data in math efficacy is checked for potential bias. Though multiple imputations were skipped over, PISA's weighting methods minimized errors.

4. Analysis and Results

This part methodologically responds to the research questions by utilizing tables and figures while maintaining consistency with the hypotheses.

Table 1: Descriptive statistics by Country and Gender (mean, SD, percentages)

Country	Gender	Math Self-Efficacy (Mean ± SD)	Math Score (Mean ± SD)	Science Score (Mean ± SD)	Reading Score (Mean ± SD)	Parental Education (Mean ± SD)
USA	Male	-0.24 (1.15)	467.21 (100.99)	500.73 (114.68)	492.25 (115.58)	Low 7%, Medium 28%, High 65%
	Female	-0.44 (1.01)	456.12 (88.24)	495.43 (102.40)	513.69 (106.13)	Low 9%, Medium 29%, High 62%
Germany	Male	-.064 (1.23)	484.56 (96.99)	497.28 (108.57)	473.60 (107.27)	Low 21%, Medium 23%, High 56%
	Female	-.34 (1.08)	470.70 (90.63)	493.14 (102.00)	491.04 (102.91)	Low 25%, Medium 19%, High 56%
Saudi Arabia	Male	-.51 (1.39)	391.49 (69.85)	382.71 (74.01)	367.94 (81.00)	Low 8%, Medium 19%, High 73%
	Female	-.47 (1.22)	389.00 (60.88)	397.24 (69.75)	398.00 (74.00)	Low 11%, Medium 21%, High 68%
Mexico	Male	-.61 (1.06)	400.50 (71.43)	417.37 (76.50)	411.63 (84.45)	Low 27%, Medium 25%, High 48%
	Female	-.73 (.99)	389.86 (66.43)	404.91 (73.1)	419.93 (81.26)	Low 33%, Medium 23%, High 44%

Notes: Math Self-Efficacy: Standardized index (mean = 0). Academic Performance: PISA plausible values (PV1MATH, PV1SCIE, PV1READ) scaled to international benchmarks. Parental Education: Ordinal variable (1 = Low, 2 = Medium, 3 = High). ***$p<0.001$, **$p<0.01$, *$p<0.05$. Gender differences are statistically significant at ***$p<0.001$. Data analyzed using repest with PISA 2022 survey weights. Data Source: PISA 2022, weighted and clustered by school ID.

The section starts with Table 1 describing a baseline distribution of major variables (math self-efficacy, academic performance, parental education) stratified by country. Table 1 shows, boys report higher math efficacy than girls in all the countries while Germany displays the highest gap.

Boys outperform girls in math and science performance (except Saudi Arabia), while girls beat boys in reading grades. Socioeconomic disparities (parental education) across countries are strong, with Saudi Arabia having most higher educated household (male 73% & female 68%) while Mexico has highest low- education household (male 27% & female 33%).

Table 2: Multicollinearity by Country (Variance Inflation Factors - VIF)

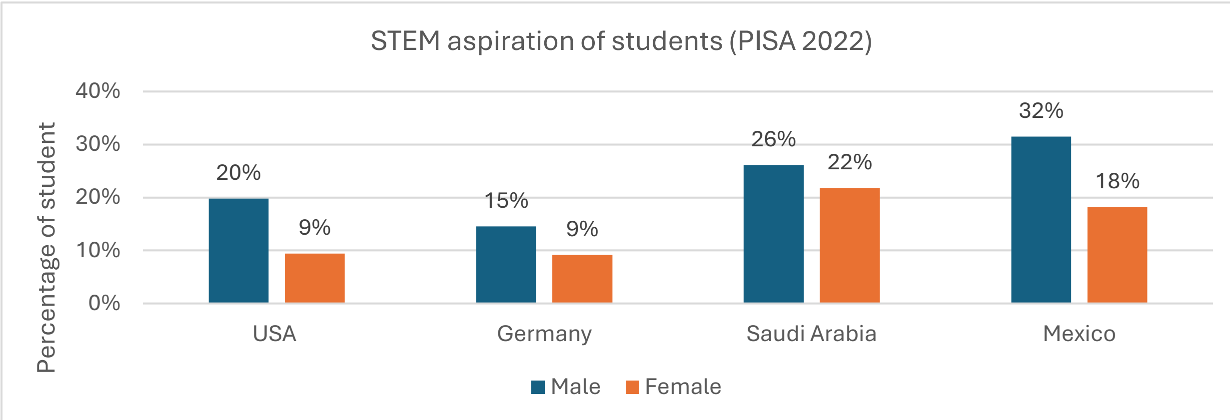
Variable	USA	Germany	Saudi Arabia	Mexico
Gender	1.1	1.12	1.12	1.07
Math efficacy	**1.31**	**1.34**	**1.1**	**1.11**
Parental Education	3.27	1.65	2.48	1.58
Math	**6.02**	**5.71**	**3.57**	**4.98**
Science	**6.74**	**5.37**	**2.96**	**4.61**
Reading	**4.88**	**4.15**	**2.79**	**3.59**

VIF Interpretation: VIF < 5 = Acceptable, VIF < 5-10 = Moderate multicollinearity, VIF > 10 = Severe multicollinearity

As expected, in table 2, the study found moderate multicollinearity between academic performances (math, science, reading) because of their cognitive interdependence, aligning with their strong correlation (Appendix D). However, the main predictor math self-efficacy was found below thresholds (VIF< 2), thus, it provides a dependable assessment of its individual connection to STEM choice. Appendix D shows global correlation matrices, and Table 2 provides country-specific VIF tests.

In every country in Figure 2, male students outnumbered female to pursue STEM careers; however, the widest gap unveiled in Mexico (14%) and smallest gap in Saudi Arabia (4%). Despite being the countries with wealth and strong gender equality, females of the US and Germany falling behind males in STEM goals between them Germany represents lower gap.

Figure 2: Cross-national differences in girls' and boys' STEM expectations



Notes: Values represent weighted proportions with standard errors in parentheses. STEM careers defined by ISCO-08 codes (e.g., scientists, engineers, ICT professionals). Data source: PISA 2022.

In the USA, model 2 reduced the gender gap to -11.2 pp with controls (Table 3). Math efficacy (largest mediator) with all the predictors covers 8.2% of the gap. Compared to lower educated, students from medium- educated households are less likely to choose STEM careers. Model 2 of Germany shows the gap of STEM aspiration (-6.3 pp) decrease to -4.4 pp. and the predictors mediate 30% of the total reduction[1] which is the highest among all the countries. In Saudi Arabia, Model 2 reduced the gap to -7.1 pp. Higher parental education is the dominant mediator and students from these families are 4.5 pp more likely to choose STEM. For Mexico, math self-efficacy significantly predicted STEM aspirations however, predictors minimally mediate the gap (4.5%). Consistent with Figure 1 and partially supporting H1, girls are notably less prone to aim for STEM occupations in all the countries (Table 3: Baseline AMEs), with math self-efficacy reduces the gap 4.5% to 30.2% while explaining 38.9% to 75% of the explained gap (Table 4). However, math self- efficacy alone does not mediate the STEM occupations gap, as parental education and academic performances also contribute to explained gap.

[1] Reduction of gap= (Baseline AME - Full Model AME/ Baseline AME) × 100.

Table 3: Mediation Effects on the Gender Gap in STEM Aspirations- AMEs (PISA 2022).

Variables	USA model 1	USA model 2/Controlled	Germany model 1	Germany model 2/ Controlled	Saudi Arabia Model 1	Saudi Arabia model 2/ Controlled	Mexico model 1	Mexico model 2/ Controlled
Female	-.122 ***	-.112***	-.063 ***	-0. 044***	-0.079***	-0.071***	-.133***	-0.127***
SE	(.011)	(0.013)	(0.010)	(0.010)	(0. 014)	(0.012)	(0.010)	(0.011)
Math-efficacy		.012 *		0.021***		0. 013***		0.020***
SE		(0.005)		(0.005)		(0.005)		(0.006)
Parental Education (Medium)		-.046*		-0. 015		0..013		-0.012
SE		(0.024)		(0.017)		(0.019)		(0.016)
Parental Education (High)		-.024		-0.009		0.045***		-0.027
SE		(0.023)		(0.017)		(0.017)		(0.015)
Math Performance		0. 0002		0. 001***		0.0005***		-0.0001
SE		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Science Performance		.0004**		0.00004		0.0002*		0.0002
SE		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Reading Performance		.0001		-.00002		0.000		-0.00005
SE		(0.0001)		(0.0001)		(0.948)		(0.0001)
Percentage of gap reduced		8.2%		30.2%		10.1%		4.5%
Observations	3,801		3,616		4,901		4,920	

Notes- Baseline Model: The gender gap (for female) without controls. Full Model: The gender gap after adding controls. % of reduced= (AMEs of **Full model** - AMEs of **Baseline model**/ AMEs of **Baseline model**) ***100.** ***p<0.001, **p<0.01, *p<0.05. Source- PISA 2022.

In contrast with H2, raw gender gaps are inconsistent with national gender equality[2] (Table 3 & 4) as Mexico share the highest gap (13.3 pp), and Germany has the lowest (6.2 pp). Moreover, noticeable country variation in mediating effects of math self- efficacy strongly supported H3 as

[2] The Global Gender Gap index 2022 ranking Germany-10th, USA- 27th, Saudi Arabia- 127th, Mexico- 31st

38.9% of USA's, 73.9% of Germany's, 42.9% of Saudi Arabia's and 75% of Mexico's explained gap is attributed to math self- efficacy (Table 4).

Table 4: Fairlie Decomposition of Gender Gap in STEM Career Aspirations (PISA 2022)

Variable	USA	Germany	Saudia Arabia	Mexico
Variables	**STEM Aspirations**	**STEM Aspirations**	**STEM Aspirations**	**STEM Aspirations**
Raw gap	0.122	0.062	0.079	0.133
Total Explained	0.018	0.023	0.007	0.004
Percentage of Explained	14.68%	36.45%	9.28%	3.69%
Percentage of Unexplained	85.32%	63.55%	90.72%	96.31%
Contributions to Explained Gap (% of Total Explained):				
Math- efficacy	38.9%	73.9%	42.9%	75%
Parental Education	11.1%	0.0%	57.1%	0.0%
Math performance	16.7%	26.1%	0.0%	25%
Science performance	33.3%	0.0%	0.0%	0.0%

Source- PISA 2022

To evaluate the robustness of the results, this thesis tested alternative model specifications with several additional covariates- Math advantage (PV1Math-PV1READ), mathematics anxiety (ANXMAT index), insight of mathematics as easier than other subject (MATHEASE), and having confidence in 21st century mathematics skills (MATHEF21). However, none of these additional covariates explained the gender gap in STEM aspiration better than original covariates. Hence, the study observed the initial theoretically based model as the precise and robust specification.

5. Discussion and Conclusion

This study conveys crucial insights into how gender, math self- efficacy and country context impacts STEM aspirations across four diverse cultural environments. Consistent with prior studies (Blasko et al., 2021; OECD, 2014a; Wang & Degol, 2013; Huang, 2013) and global trends, girls have significantly lower STEM aspirations than boys however, the reason behind this gap are not universal- challenging the straightforward arguments of gender equality and STEM goals. The cross-national gender gap in STEM expectations (Figure 2) exists across all the countries, while Germany revealing the smallest (9% boys vs. 5% girls) and Mexico the largest gap (22% boys vs. 11% girls). This result challenges the gender-equality paradox as Germany (high-equality) maintains that smaller STEM gaps, while Mexico (low-equality) validates institutional drivers can dominate individual competence. Math efficacy mediates gender gaps; however, its mediation strength differs significantly depending on the countries. H1 is partially supported (Table 3) as math self-efficacy is a strong indicator of STEM aspirations, yet it shows weakest mediation explaining only 4.5% of the gap in Mexico and 30% in the Germany. This variation doesn't verify that self-efficacy doesn't matter for STEM aspirations in Mexico as its effect size is almost similar to Germany's (respectively AME=0.020 and 0.021), instead due to the self-efficacy levels of girls in Mexico are almost equal to those of boys (Table 1). The smaller gender gap in self-efficacy in Mexico (-0.61 - (-0.73) = 0.12) suggests it has less gap to mediate than Germany's larger self-efficacy gap (0.28), though self-efficacy increases STEM aspirations in both countries.

Thus, the mediating role of math self-efficacy constantly depends on context, which strongly confirms H3. Fairlie decompositions (Table 4) reveals in-depth variations as self-efficacy accounts for 38.9%–75% of the explained gaps, while unexplained gaps are larger in significance (for example, 96.3% in Mexico). This insight indicates how institutional dynamics dominate cognitive mechanisms. Germany's strong mediation persists along strict early academic sorting which pushes adolescents into academic and vocational career paths, driving girls into culturally "feminine" career like nursing or caregiving (Hamilton, 1999), worsening the efficacy gaps. Mexico's insufficient mediation expresses the lack of resources as 33% of girls are from lower educated households, resulting in efficacy less apparent although it is a strong indicator. Parental education controls 57% of the mediation proposes that policy reforms of Vision 2030 successfully overcome institutional challenges and shifting towards social barriers. Additionally, the USA's female dominated careers (e.g., 37% girls aspirations clustering in healthcare; Hall & Rathburn, 2020) can conceal the real scenario of gender gap in STEM aspirations.

These findings challenge the gender-equality paradox and rejected H2. The smaller gap in Germany suggest that gender gaps in STEM goals are not inevitable, rather policy responsive. The spike in female STEM participation in Saudi Arabia after Vision 2030 (Babineau, 2023) confirms that targeted investment can surpass structural challenges. As a result, female enrollment in STEM education increased 30% since 2016 as a result of government schemes such as women-exclusives STEM campuses, scholarships and collaboration with international tech companies (Babineau, 2023).

The analysis overall reveals that math efficacy independently is insufficient to predict STEM aspirations. Expected trade-offs (Stoet & Geary, 2018) between gender equality and STEM equity declined as Germany could minimize its STEM gap considering its dual advantages- higher gender equality in society and robust math efficacy mediation outcome. Furthermore, females illustrated significant intra-individual advantage in reading than males across all the countries (+12.71 vs. −17.92; Appendix E) suggesting that despite female have comparable performance in math, their higher reading skills expand career opportunities beyond STEM. Hence, in countries with diverse educational tracks, females' competency in several areas tend to shift them towards fields like healthcare, social sciences, or journalism- typically considered as "feminine" and well-matched with verbal skills (Charles & Bradley, 2009).

The results of this study demand country-specific policy interventions, proposing that to mitigate the persistent gender gap in STEM aspirations, policy makers must adapt schemes to the structural and institutional circumstances of each country. For example, in USA by highlighting female role models in sectors focused on men-such as in engineering, ICT, science, and physics it can mitigate the gender gap in STEM aspirations. For Germany, delaying academic sorting until late adolescence, and incorporating STEM courses in vocational programs might significantly alleviate the gender gap in STEM. Promoting female role models in male dominated sectors and mentorship programs and recruiting more female teachers from STEM fields might override parental education and raise STEM aspiration among girls in Saudi Arabia. Investing in rural STEM organizations, enhancing mentorship programs, and scholarship aid can raise opportunities for girls to rely on their self-efficacy in Mexico.

Although this study provides insightful analysis, several limitations must be admitted- using single (PV1) plausible values for academic performance, and longitudinal studies are not taken under consideration. While these decisions reduce complexity and increase analysis efficiency, these may also reduce the generalization of the results. Future studies should be strengthened by applying all 10 PISA plausible values to capture academic performance, employ longitudinal designs and in-depth approach to Mexico's unexplained gaps.

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7. Appendix

Appendix A: STEM career expectation code, recoded from ISCO-88

21 Science and engineering professionals 211 Physical and earth science professionals 2111 Physicists and astronomers 2112 Meteorologists 2113 Chemists 2114 Geologists and geophysicists 212 Mathematicians, actuaries and statisticians 2120 Mathematicians, actuaries and statisticians 213 Life science professionals 2131 Biologists, botanists, zoologists and related professionals 2132 Farming, forestry and fisheries advisers 2133 Environmental protection professionals 214 Engineering professionals (excluding electrotechnology) 2141 Industrial and production engineers 2142 Civil engineers 2143 Environmental engineers 2144 Mechanical engineers 2145 Chemical engineers 2146 Mining engineers, metallurgists and related professionals 2149 Engineering professionals not elsewhere classified	215 Electrotechnology engineers 2151 Electrical engineers 2152 Electronics engineers 2153 Telecommunications engineers 216 Architects, planners, surveyors and designers 2161 Building architects 2162 Landscape architects 2164 Town and traffic planners 2165 Cartographers and surveyors 25 Information and communications technology professionals 251 Software and applications developers and analysts 2511 Systems analysts 2512 Software developers 2513 Web and multimedia developers 2514 Applications programmers 2519 Software and applications developers and analysts not elsewhere classified 252 Database and network professionals 2521 Database designers and administrators 2522 Systems administrators 2523 Computer network professionals 2529 Database and network professionals not elsewhere classified

Appendix B: Global Gender Gap Report, 2022

United States 27th

Germany 10th

Mexico 31st

Saudi Arabia 127th

- World Economic Forum's Global Gender Gap Report, 2022 expresses gender parity in a rank format in which low ranks predict countries have less gender gaps.

Appendix C: Percentage of missingness by country

Country	STEM expectations (%)	STEM expectations (%) without non-responsive answer	Math Self-Efficacy (%)	Gender (%)	Parental Education (%)	Total (N)
USA	15.25	0.72	12.57	0.11	4.90	4552
Germany	35.84	0	21.55	00	16.84	6116
Saudi Arabia	27.34	8.59	15.04	00	2.17	6928
Mexico	20.61	0.51	9.88	00	0.40	6288

Source- PISA 2022.

Appendix D: Correlation Matrix

Variable	MATHEFF	PV1MATH	PV1SCIE	PV1READ
MATHEFF	1			
Math	**0.416**	1		
Science	**0.365**	0.884	1	
Reading	**0.315**	0.823	0.827	1

Notes: correlations significant at $p < 0.001$. Source- PISA 2022.

Appendix E: Gender gaps in Intra-Individual Reading-Math Differences (PISA 2022)

Gender	Mean (SD)	Min	Max
Male	−17.92 (60.50)	−352.54	326.94
Female	12.71 (59.28)	−356.60	315.09

Note- **Intra-individual gap**: Reading performance (PV1READ) – Math performance (PV1MATH). Data source: PISA 2022.