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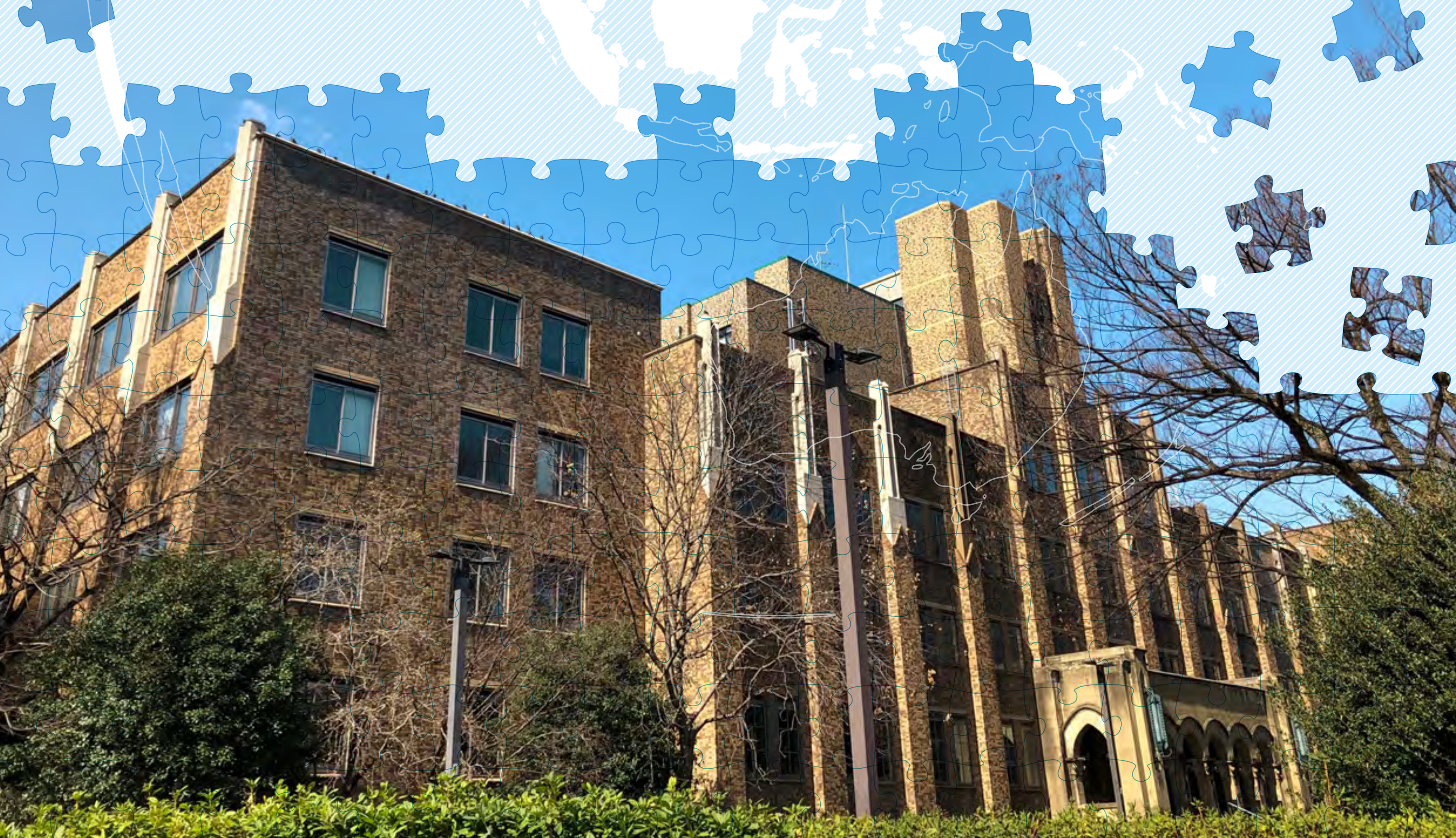
Exploring Pathways to Gender Inequality in STEM Choices: Insights from the Embedded Mechanism in the Japanese Context



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Exploring Pathways to Gender Inequality in STEM Choices: Insights from the Embedded Mechanism in the Japanese Context

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Abstract

Despite global advancements in educational access, women remain underrepresented in STEM fields worldwide, including in Japan. This study explores the factors contributing to gender inequality in STEM choices among Japanese students, focusing on the relative importance of two mechanisms: the academic pipeline and the dream pipeline. By utilizing longitudinal data from Japanese students from elementary through high school, this paper finds that academic self-concepts and preferences play a more significant role in explaining gender inequality in Japan than do occupational plans, which are emphasized as important factors, especially in the United States. Specifically, academic preferences account for 33%, academic self-concept accounts for 20%, and occupational plans account for only 9% of the gender gap in STEM choices. This paper also reveals that gender disparities are already present at the start of elementary school and remain stable throughout school education. Females consistently show greater academic self-concepts and preferences in language, whereas males prefer mathematics and science and aspire to STEM-related professions. These findings from a non-Western context suggest that the mechanism behind gender disparities in STEM choices is embedded in the social context and highlight the need to examine the early childhood factors that contribute to the formation of gender disparities. Further research should include cases from other countries to obtain a more comprehensive understanding.

Keywords: Gender inequality, STEM field choices, Japan

1. Introduction

Despite global advancements in educational access, women remain consistently underrepresented in science, engineering, technology, and mathematics (STEM) fields worldwide (OECD 2023). The increasing enrollment of women in universities often coincides with gender-segregated majors, leading to occupation-specific domains separated by gender (Shauman 2006). Consequently, understanding why women tend to choose STEM fields less frequently remains crucial.

Numerous scholarly discussions have explored the factors influencing women's lower inclination toward STEM fields than that of men, with two explanations at the forefront, namely, the academic pipeline and the dream pipeline (Correll 2001; Morgan, et al., 2013; Riegle-Crumb and Peng 2021; Weeden, et al. 2020; Xie and Shauman 2003). The former suggests that gender disparities in academic performance are key to explaining gender inequality in STEM choices. Specifically, women often perceive their mathematical skills more pessimistically than men do and thus have a lower preference for mathematics (Correll 2001; Thébaud and Charles 2018; Xie and Shauman 2003), which distances them from STEM fields. The latter suggests that gender differences in occupational career perspectives can contribute to gender inequality in STEM. Men typically prioritize economic benefits, whereas women are inclined toward altruistic gains (Ma 2009; Quadlin 2020; Zafar 2013) and are often deterred from STEM careers because of perceived gender role difficulties (Weisgram and Diekman 2017). Compared with male high school students, female high school students are less likely to aspire to STEM careers, which helps to explain gender segregation in STEM fields (Morgan et al. 2013; Weeden et al. 2020).

While previous empirical studies have made efforts to elucidate why women tend to avoid choosing STEM fields, two major issues need to be addressed in this paper. First, these studies have focused primarily on two separate mechanisms, namely, the academic pipeline and the dream pipeline, without thoroughly discussing their respective relative importance. Although the specifics of individual mechanisms are discussed in detail, uncertainty remains regarding which explanation better accounts for gender inequality. In one of the notable exceptions, Weeden et al. (2020) examined the relative importance of these mechanisms, arguing that the dream pipeline, which is characterized by differences in occupational aspirations during high school, holds greater significance than the academic pipeline in explaining gender disparities in STEM fields, at least within the United States. However, it is essential to carefully consider whether the dream pipeline is universally crucial as an explanation, as the relative importance of these mechanisms may vary depending on societal structures. As Barone and Assirelli (2020) noted, since most empirical studies are focused on the United States, it is necessary to contextualize the findings of previous research from other countries.

The second issue that needs to be examined is when and how the academic and dream pipelines arise through school education. Many studies have examined whether school education functions to reduce educational disparities from a socioeconomic perspective, reaching the consensus that schools tend to maintain existing inequalities rather than creating disparities in cognitive ability (Downey, Kuhfeld, and Van Hek 2022; Passaretta and Skopek 2021; Von Hippel, Workman, and Downey 2018). However, with respect to gender inequality, it has not been discussed whether these differences arise at the time of school entry or gradually emerge through the course of school education, while the importance of gender differences in academic self-concept and occupational plans has been noted. As a rare exception, Downey et al. (2022) reported an intriguing result, suggesting that gender differences in cognitive abilities widen in the absence of schooling and diminish when schooling is present in the United States. While they focused on the summer vacation gap, it is also necessary to examine when and how gender disparities arise throughout the entire period of school education from elementary to high school.

This paper aims to enhance our understanding of gender disparities in STEM field choices by investigating the relative significance of mechanisms that elucidate these disparities and when and how academic and dream pipelines arise through school education within the Japanese context. Japan presents a particularly compelling case study setting because its proportion of female graduates in STEM fields is lower than the OECD average, which stands at less than 20% (OECD, 2023). One contributing factor might lie in Japan's unique process for selecting fields of study. In Japan, students are required to choose their field of study during high school because Japanese universities have required entrance examinations according to the departments that students wish to enter. The Japanese context provides a compelling case for examining how preuniversity factors shape gender disparities in the selection of academic fields in a non-Western context.

2. Theoretical Background

2.1. Explanation of the academic pipeline

The predominant metaphor used to explain the underrepresentation of women in STEM fields is the pipeline model, which suggests a relatively inflexible, linear progression through a predetermined series of transition points in educational and occupational trajectories (Berryman, 1983). Since prior academic preparation and attitudes toward math and science are the strongest predictors of entrance into a STEM major in college (Tai et al. 2006), the underrepresentation of women in STEM fields is often discussed because of lower levels of academic qualifications or diminished interest and inclination toward such fields (Hilton and Lee 1988; Oakes 1990; Smyth and McArdle 2004). Although numerous factors contribute to the leakage of women from the pipeline toward STEM fields, older studies tend to attribute the gender gap in STEM fields to differences in objective academic achievement (Berryman, 1983; Dunteman et al. 1979; Goldman and Hewitt 1976). For instance, Berryman (1983) noted that fewer women pursue careers in STEM fields due to their lower math test scores early in their educational careers, stemming from comparatively weaker math preparation in high school. Consequently, this results in lower math scores in the 12th grade, as females take fewer advanced math classes than males do. Similar arguments, which attribute the underrepresentation of women in STEM fields to academic underachievement during the early stages of their educational careers, are also prevalent in other previous empirical studies (Dunteman et al., 1979; Goldman and Hewitt 1976).

However, in many countries, it has been reported recently as a common consensus that there is either no significant gender difference in objective academic performance or that if there is, it is too small to explain the gender gap in STEM choices (Hyde et al. 2008; Riegle-Crumb et al. 2012; Simon and Farkas 2008). Xie and Shauman (2003) reported that while objective academic scores in math and science are strongly associated with the choice of STEM majors, the slight gender gap in math aptitude favoring males is too small to account for the substantial gender disparity in STEM selection. Riegle-Crumb and King (2010) confirmed similar results by reexamining the data used by Xie and Shauman (2003) and incorporating the latest cohort data, suggesting that math attitudes during high school do not contribute significantly to disparities in the choice of STEM fields. Even when the ratio of math test scores to verbal test scores is considered, the explanatory power of the objective math ability score itself in gender segregation in STEM fields is shown to be small in the United States (Riegle-Crumb et al. 2012).

Therefore, previous studies have underscored the importance of subjective academic factors such as academic self-concept and preferences for mathematics and science rather than solely focusing on gender differences in objective academic scores (Correll 2001; Kudenko and Gras-Velazquez 2016; Thébaud and Charles 2018). For example, Catsambis (1995) reported that female middle and high school students tend to exhibit less interest and confidence in mathematics than their male counterparts do, despite their similar levels of objective performance. Correll (2001) also demonstrated that women tend to perceive their mathematical skills more pessimistically than men do, even after adjusting for performance levels. While both males and females are influenced by friends' preferences for favorite subjects in the classroom, the influence of friends tends to be stronger for males, thereby reinforcing their preferences for STEM fields (Raabe, Boda, and Stadtfeld 2019). Ultimately, male students tend to develop preferences for STEM subjects, whereas female students tend to develop preferences for non-STEM subjects over the course of their school education (Cheryan et al. 2011; Reilly, Neumann, and Andrews 2016) because of feedback received from socializers within the expectancy-value model (Eccles 2011).

2.2. Explanation of the dream pipeline

Although academic achievement becomes an important dependent variable when the mechanisms by which gender inequality is generated within schools are considered, prior research offers limited support for these academic pipeline explanations for gender inequality in STEM. While academic self-concepts or preferences for mathematics are at least much more important than actual academic achievement (Kudenko and Gras-Velazquez 2016) and gender differences in students' perceptions of the difficulty of mathematics are associated with gender differences in declaring STEM majors (Nix and Perez-Felkner 2019), these associations frequently fail to significantly mediate gender inequality in STEM (Nix and Perez-Felkner 2019; Riegle-Crumb and King 2010).

In the context of the relatively weak explanatory power of the academic pipeline, Morgan et al. (2013) noted that gender differences in occupational plans have rarely been considered in discussions about gender inequality, despite the common inclusion of occupational aspirations in models discussing the effects of socioeconomic background on educational attainment, such as the relative risk aversion (RRA) hypothesis (Breen and Goldthorpe 1997). They found that occupational plans can explain as much as 52% of the gender difference in college major selection, underscoring the significance of the dream pipeline. Weeden et al. (2020), who extensively discussed the relative importance of the academic pipeline and the dream pipeline, arrived at a similar conclusion. They reported that objective academic scores, self-assessed math ability, and orientation toward family and work explain no more than approximately 12% of the gender differences in major selection in STEM, whereas approximately 32% of these differences are explained by occupational plans formed during high school. On the basis of these findings, they argued that efforts should prioritize enhancing entry into science-related careers rather than solely focusing on improving women's test scores or confidence.

As both Morgan et al. (2013) and Weeden et al. (2020) argued, gender differences in occupational plans themselves are significant, and occupational preferences, including orientation toward family and work, do not fully explain the gender gap in STEM (Mann and DiPrete 2013; Morgan et al. 2013; Riegle-Crumb et al. 2012; Weeden et al. 2020). Students tend to express concerns that STEM fields lead to careers that are difficult to combine with family life (Ganley et al. 2018), and these prospects lower the probability of choosing STEM fields (Wiswall and Zafar 2018). Additionally, women may tend to opt for less lucrative fields because they are more family-oriented and thus attach lower value to prestige, earnings, and career prospects, while they prioritize family conciliation and expressive motives such as self-realization and "indulging gendered selves" (Ceci and Williams 2010; Charles and Bradley 2009). However, gender differences in occupational preferences have not been very pronounced in recent cohorts, thereby lacking explanatory power for gender inequality (Mann and DiPrete 2013; Menon et al. 2017; Morgan et al. 2013; Riegle-Crumb et al. 2012; Weeden et al. 2020). Although the explanatory power of occupational plans in contexts outside the United States is not entirely clear, it has been argued that the dream pipeline, which is defined by occupational plans, holds greater importance than the academic pipeline, which is defined by academic self-concepts and preferences, at least in the United States (Morgan et al. 2013; Weeden et al. 2020). This paper discusses the relative importance of the mechanisms of gender inequality in STEM choices in Japan, contextualizing the findings of previous studies by focusing on a non-Western context.

2.3. Does school worsen gender inequality?

While the number of studies analyzing the relative importance of occupational plans is limited, previous research consistently shows that a significant portion of gender inequality emerges long before individuals choose a major field of study, even outside the United States (Barone and Assirelli 2020; Justman and Méndez 2018; Legewie and DiPrete 2014; Morgan et al. 2013; Riegle-Crumb and King 2010). For example, in an Australian study, Justman and Méndez (2018) did not explore the explanatory role of occupational plans, as emphasized in the United States. However, their findings align with those of other studies, indicating that objective academic scores do not explain the gender gap in STEM field choices and that disparities in STEM-related subjects are noticeable as early as secondary school. Similarly, in an Italian study, Barone and Assirelli (2020) did not examine occupational plans but still affirmed the limited explanatory power of objective academic scores. They argued that the selection of educational tracks in upper secondary education is crucial, suggesting that gender segregation in higher education is to some extent determined before high school graduation. The existing research landscape not only emphasizes the need to further validate the relative importance of the academic pipeline and the dream pipeline outside the United States but also underscores the necessity of examining how gender disparities in academic self-concept, preferences, and occupational plans manifest throughout school education.

Although numerous studies have examined whether school education mitigates educational disparities from a socioeconomic standpoint (Downey et al. 2022; Passaretta and Skopek 2021; Von Hippel et al. 2018), the discussion of gender inequality has yet to explore whether these differences arise at the beginning of schooling or gradually over the course of education. However, some studies have implied that gender disparities widen through school education. For example, Kersey et al. (2018) suggested that gender differences in objective test scores for mathematics and science are minimal in early childhood but gradually widen from elementary school onward (see also Hyde et al. 2008). Gender disparities might increase gradually with the time at which individuals choose their majors because students are exposed to socializers who promote socialization aligned with gender norms after they enter elementary school, such as friends (Raabe et al. 2019; Smith and Farkas 2023), teachers, and parents (Bleeker and Jacobs 2004; Solanki and Xu 2018). Additionally, gender differences from future perspectives tend not to emerge in early childhood but become apparent during adolescence, as individuals begin to contemplate their futures (Weisgram, Bigler, and Liben 2010), with beliefs about STEM careers conflicting with family formation strengthening as children age (Weisgram and Diekman 2017). Longitudinal data are needed to examine whether gender disparities in academic self-concept, preferences, and occupational plans genuinely increase as students mature. This paper addresses this second challenge via unique longitudinal data from Japan that spans 12 grades ranging from elementary school to high school.

3. Japanese Context

The Japanese context provides a compelling case for examining how preuniversity factors influence gender disparities in the selection of academic fields because of its unique process for selecting fields of study. Historically, Japanese universities have established quotas for admission to each department, and entrance exams are conducted accordingly. For example, students aiming to enter the engineering department must take entrance exams in mathematics and science, whereas those aspiring to enter the literature department need to excel in exams covering both Japanese and English. Because students must prepare for entrance exams that are specific to their desired department, they are required to make decisions about their specialization early on. Generally, high school students choose between STEM tracks or non-STEM tracks in the latter half of their first year of high school[1]. To prepare for entrance exams specific to their respective departments, students in the STEM track focus on mathematics and science, whereas those in the non-STEM track focus on Japanese language and social studies, without the need to further study mathematics and science.

This Japanese context enables the examination of how gender inequality arises in situations where students must choose their fields of specialization at a relatively early stage because it is nearly impossible to change their academic trajectory once assigned to the track chosen in their first year of high school. Additionally, Japanese high school students do not necessarily choose STEM fields on the basis of socioeconomic benefits because income levels are not consistently higher for graduates in STEM fields within the Japanese labor market (Yamamoto et al. 2015); however, significant wage disparities exist between majors, with STEM graduates often commanding higher salaries in the United States (Kim et al. 2015). This lack of financial motivation does not encourage students to select STEM majors on the basis solely of socioeconomic benefits or considerations of work–life balance. The relatively small differences in wages and working conditions across occupations in the Japanese context contribute to contextualizing the findings of American studies emphasizing the relative importance of gender disparities in occupational plans.

4. Methods

4.1. Data and sample

I use data from the Japanese Longitudinal Study of Children and Parents (JLSCP). This longitudinal study was conducted annually from 2015 (wave 1) to 2021 (wave 7) by the Institute of Social Science at the University of Tokyo and the Benesse Educational Research and Development Institute. Initially, the study targeted children and their parents across 10 different grade levels[2], i.e., from 1st-grade elementary school students to 3rd-year high school students, in 2015. The study subsequently continued to follow the participants up to the 3rd year of high school, while adding a new sample of 1st grade elementary school students each year. The survey aimed to be nationally representative of Japan by selecting participants based on gender and residential area from the Benesse Educational Research and Development Institute's survey monitors.[3] During the third year of high school, an additional graduation survey was conducted to investigate students' intended university departments and their future aspirations.[4] This study is suitable for the current purpose because it utilizes variables related to academic self-concept, academic preferences, and occupational plans before students choose their specialization. It also allows us to examine changes in gender disparities from elementary school entry to high school graduation.

I utilize two samples. The first sample consists of responses from high school seniors who participated in the graduation survey (3,866 observations). The second sample comprises person-years of children from 1st grade in elementary school to the 1st year high school (94,229 observations). Using the former sample, I examine the relative importance of both the academic pipeline and dream pipeline in explaining gender inequality in STEM choices and assess when and how these factors manifest using the latter sample. I do not include 2nd- or 3rd-year high school students in the latter person-year data because math and science are considered mandatory subjects only until the first year of high school. Therefore, in the analysis of the graduation survey data, I also utilize information from the first year of high school, which leads to the choice of college major.

4.2. Variables

The primary dependent variable is enrollment in a STEM department. In the additional graduation survey, high school seniors responded to the following question: *"What field of study will you major in at your chosen university?"*, with answer options including non-STEM, STEM, medical, arts, and other fields of study. The independent variable is gender, and I examine how gender influences the STEM pathway, with a focus on the distinction between choosing non-STEM and STEM fields, whether through academic or occupational pathways.

Table 1: Descriptive statistics of the variables used in the analysis

	Sample 1		Sample 2	
	N	Mean	N	Mean
College major Choice				
non-STEM	3837	0.301		
STEM		0.178		
Medical		0.088		
The others		0.433		
Gender				
Male	3,866	0.473	92,778	0.494
Female		0.527		0.506
Academic Selfconsept				
Language	3,288	3.292	86,002	3.525
Mathematics	3,289	3.279	85,957	3.634
Social Studies	3,240	3.239	56,535	3.495
Science	3,244	3.281	56,523	3.565
Academic Preference				
Language	3,291	2.515	91,456	2.711
Mathematics	3,290	2.554	91,494	2.901
Social Studies	3,241	2.591	67,489	2.805
Science	3,248	2.596	67,541	2.983
Occupational Plan				
STEM Proffesions	3,278	0.060	32,906	0.080
Healthcare professions		0.059		0.050
non-STEM professions		0.093		0.072
Other professional occupations		0.059		0.136
Clerical and sales positions		0.048		0.046
Blue-collar jobs		0.050		0.083
The others		0.089		0.079
Undecided		0.543		0.454
Grade Levels				
1st grade			92,778	0.135
2nd grade				0.124
3rd grade				0.118
4th grade				0.104
5th grade				0.097
6th grade				0.091
7h grade				0.086
8th grade				0.083
9th grade				0.083
10th grade				0.079
12th grade	3,866	1.000		0.000

The academic pipeline is defined by children's academic self-concepts and academic preferences in subjects such as language, mathematics, social studies, and science. Each year, children rate their academic self-concept on a 5-point scale ranging from 1 (low) to 5 (high). Additionally, they rate their academic preferences on a 4-point scale ranging from 1 (low) to 4 (high). Since social studies and science become mandatory starting from the 3rd grade of elementary school and responses are collected from the 4th grade onward, there is no information available for the 1st, 2nd, and 3rd grades of elementary school. The dream pipeline consists of occupational plans categorized into eight groups, namely, STEM professions, healthcare professions, non-STEM professions, other professional occupations, clerical and sales positions, blue-collar jobs, other, and undecided.[5] From the 4th grade of elementary school onward, children specify their desired future occupations in a free-text field each year. These responses are later transcribed and coded by the Institute of Social Science at the University of Tokyo. The descriptive statistics of the variables used in the analysis are shown in Table 1.

4.3. Statistical methods

First, I estimate a multinomial logistic regression analysis using data from the graduation survey conducted in the third year of high school, with enrollment in non-STEM departments as the reference category. I investigate how the effect of gender on enrollment in STEM departments is explained by academic self-concept, academic preference, and occupational plans measured during the first year of high school. Next, I estimate interaction terms between gender and grade level via a random effects model with person-year data from 1st grade in elementary school to the 1st year of high school. This analysis aims to elucidate when and how gender inequality emerges through school education. I perform imputation to correct missing values via multiple imputation methods and discuss the average marginal effects graphically.

5. Results

5.1. Analysis 1: The relative importance of the academic and dream pipelines

In Table 1, I present the results of a multinomial logistic regression analysis on advancing into a STEM department, with advancing into a non-STEM department as the reference category. The average marginal effects are shown to facilitate interpretation. A review of the baseline model, i.e., Model 1, reveals that the probability of females advancing into a STEM department is 0.123 lower than that of males. To explain the gender disparities, academic self-concepts are included in Model 2, academic preferences are included in Model 3, and occupational plans are included in Model 4 as mediating variables. In Model 5, all factors are simultaneously controlled for.

In Model 2, which includes academic self-concept, I observe that for high school freshmen who are considering the department they wish to enter, a one-point increase in academic self-concept for language decreases the likelihood of choosing a STEM field by approximately 0.033 and that for social studies decreases the likelihood by approximately 0.018. In contrast, a one-point increase in academic self-concept for mathematics increases the likelihood of choosing a STEM field by approximately 0.03 and that for science increases the likelihood by approximately 0.06. Controlling for academic self-concept reduces the average marginal effect of gender from -0.123 to -0.099, indicating that approximately 19.5% of the gender gap can be explained by differences in academic self-concept. Nevertheless, even with equal academic self-concepts, females are still less likely to choose STEM fields.

In Model 3, which includes academic preference, we find that a one-point increase in preference for language decreases the likelihood of choosing a STEM field by approximately 0.037, and that for social studies decreases the likelihood by approximately 0.016. Conversely, a one-point increase in preference for mathematics increases the likelihood of choosing a STEM field by approximately 0.041 and that for science increases the likelihood by approximately 0.065. Controlling for academic preference reduces the average marginal effect of gender from -0.123 to -0.085, explaining approximately 30.7% of the gender gap. These findings suggest that academic preference is relatively more significant than academic self-concept. However, even with equal academic preferences, females remain less likely to choose STEM fields.

Having confirmed the explanatory power of the academic pipeline, let us now look at Model 4, which includes occupational plans, a factor emphasized in existing American research. The average marginal effect of occupational plans shows that, indeed, whether a student aspires to a STEM profession is significant; such high school students are 0.107 more likely to choose a STEM field. Conversely, those aiming for non-STEM professions are approximately 0.051 less likely to choose a STEM field, those aiming for clerical and sales professions are approximately 0.119 less likely to do so, and those aiming for blue-collar jobs are approximately 0.071 less likely to do so. This finding indicates that occupational plans are closely linked to college major choice. However, compared with subjective academic ability, occupational plans do little to explain gender inequality in STEM choice. The average marginal effect of gender decreases from -0.123 to -0.113, explaining only approximately 8.5% of the gender gap, which is much lower than the 30.7% explained by academic preference and the 19.5% explained by academic self-concept. Therefore, even if occupational plans remained the same, females would still be 0.113 less likely to choose STEM fields. This finding indicates that, at least in the context of Japan, the explanatory power of the dream pipeline is relatively low compared with that of the academic pipeline. This suggests that the dream pipeline is not a universal mechanism for gender inequality in STEM choices and that its relative importance is embedded in social structures.

Table 2: Average Marginal Effect of Gender on STEM Choices Relative to Non-STEM

	Model 1		Model 2		Model 3		Model 4		Model 5	
	AME	*S.E.*	*AME*	*S.E.*	*AME*	*S.E.*	*AME*	*S.E.*	*AME*	*S.E.*
Gender (ref. Male)										
Female	-0.123 ***	0.012	-0.099 ***	0.012	-0.085 ***	0.012	-0.113 ***	0.013	-0.077 ***	0.013
Academic Selfconsept										
Language			-0.033 ***	0.007					-0.018 *	0.008
Mathematics			0.030 ***	0.007					0.016 *	0.008
Social Studies			-0.018 *	0.008					-0.007	0.009
Science			0.060 ***	0.009					0.034 ***	0.010
Academic Preference										
Language					-0.037 ***	0.008			-0.018	0.010
Mathematics					0.041 ***	0.008			0.022 *	0.010
Social Studies					-0.016 *	0.008			-0.009	0.009
Science					0.065 ***	0.009			0.047 ***	0.010
Occupational Plan (ref. Undecided)										
STEM Proffesions							0.107 ***	0.024	0.054 *	0.024
Healthcare professions							0.046	0.030	0.019	0.029
non-STEM professions							-0.051 *	0.025	-0.051 *	0.025
Other professional occupations							-0.105 **	0.036	-0.090 *	0.036
Clerical and sales positions							-0.119 **	0.039	-0.111 **	0.037
Blue-collar jobs							-0.070 *	0.035	-0.059	0.034
The othres							-0.037	0.024	-0.033	0.023
-2 Loglikelihood	10726.38912		10412.50073		10353.46058		10395.76622		9999.00	
N					3,866					

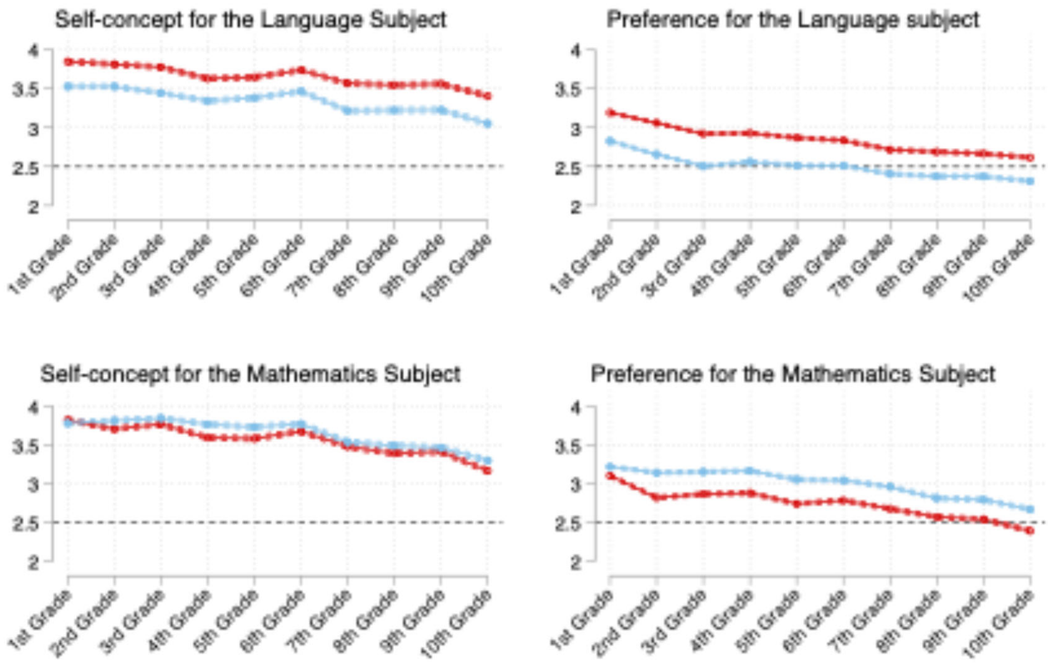
***: p<0.001, **: p<0.01, *: p<0.05

Finally, the results of Model 5, which includes academic self-concept, academic preference, and occupational plans, suggest that even if these factors are equal, females are still less likely to choose STEM fields than males. Specifically, for mathematics, a one-point increase in academic self-concept increases the likelihood of choosing a STEM field by approximately 0.016, and a one-point increase in academic preference increases the likelihood by approximately 0.022, even when controlling for mutual subjective academic factors. The same direct effect can also be observed for science. Additionally, if a student is considering a STEM profession, they are approximately 0.054 times more likely to choose a STEM field, even if their academic self-concept and preference are at the same level. However, even after controlling for all these factors, females are still 0.077% less likely to choose STEM fields than males, and the proportion of the gender gap explained is approximately 37.1%. This leaves 62.9% of the gap unexplained by either the academic pipeline or the dream pipeline.

5.2. Analysis 2: When and how does the gender gap arise?

To examine how the gender gap emerges during the first year of high school, Figure 1 illustrates the average marginal effects of gender on academic self-concepts and academic preferences in both language and mathematics subjects across different grade levels. In the Japanese context, interestingly, women's academic self-concept is not low; rather, women's academic self-concept in language is significantly greater. Considering the trend of gender differences in academic self-concepts for language, females tend to have greater academic self-concepts than males do, starting at the beginning of elementary school; this gender difference persists without expansion or contraction until the first year of high school. Similarly, with respect to academic preferences in language, females already show a preference for language compared with males upon entering elementary school, and this gender difference remains stable without expanding or contracting up to the first year of high school. These findings suggest that women are more likely to be channeled into non-STEM fields due to greater self-concepts and preferences for language, indicating that focusing solely on STEM subjects such as mathematics may lead to overlooking the mechanisms that give rise to gender inequality.

Figure 1: Changes in gender disparities in academic performance between language and mathematics across grade levels



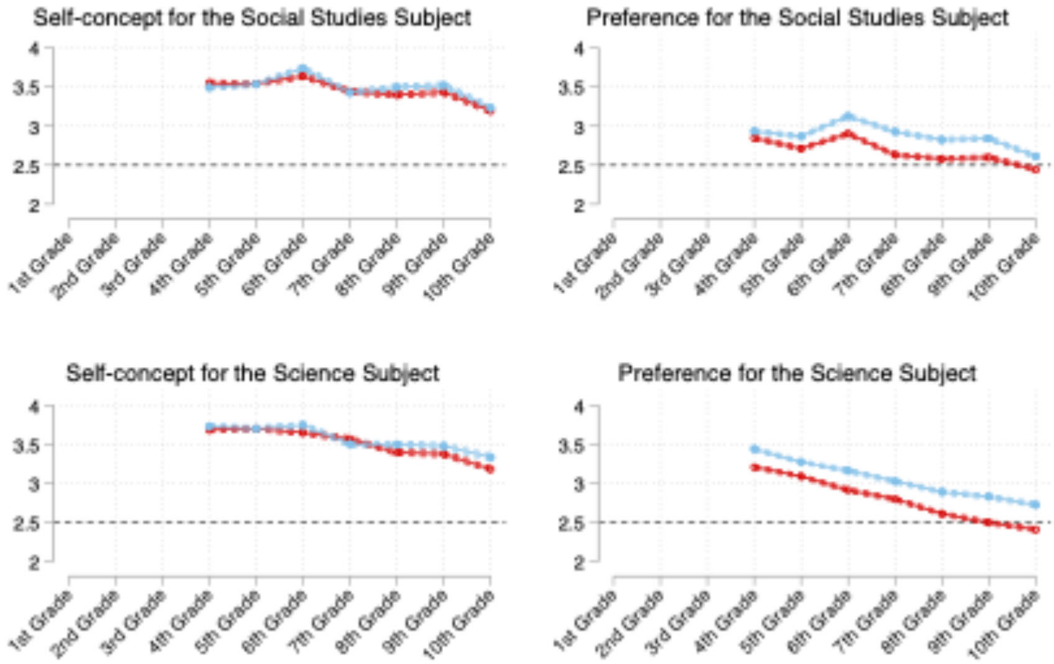
Notes: The red line represents females, whereas the blue line represents males.

When grade-level changes in academic self-concept and academic preference related to mathematics are examined, gender differences are less pronounced than those observed in language. Specifically, in academic self-concept in mathematics, there is a slight increase in the fourth and fifth grades of elementary school, but there is almost no statistically significant gender difference. In contrast, academic preference shows a stronger tendency toward gender differences. While the gender difference is relatively small in the first grade of elementary school, it significantly expands by the second grade and remains stable without expansion or contraction until the first year of high school.

A similar pattern is observed for social studies and science. Figure 2 illustrates the average marginal effects of gender on academic self-concepts and academic preferences in both social studies and science subjects across different grade levels. While statistically significant gender differences in academic self-concepts are not observed in either social studies or science, gender differences in academic preferences emerge around fourth grade and remain relatively stable thereafter. Compared with males, females may not necessarily have lower academic self-concepts in social studies or science. However, they are less likely to develop a preference for these subjects than males are. Overall, the gender gap in academic self-concept and preference does not gradually emerge through school education.

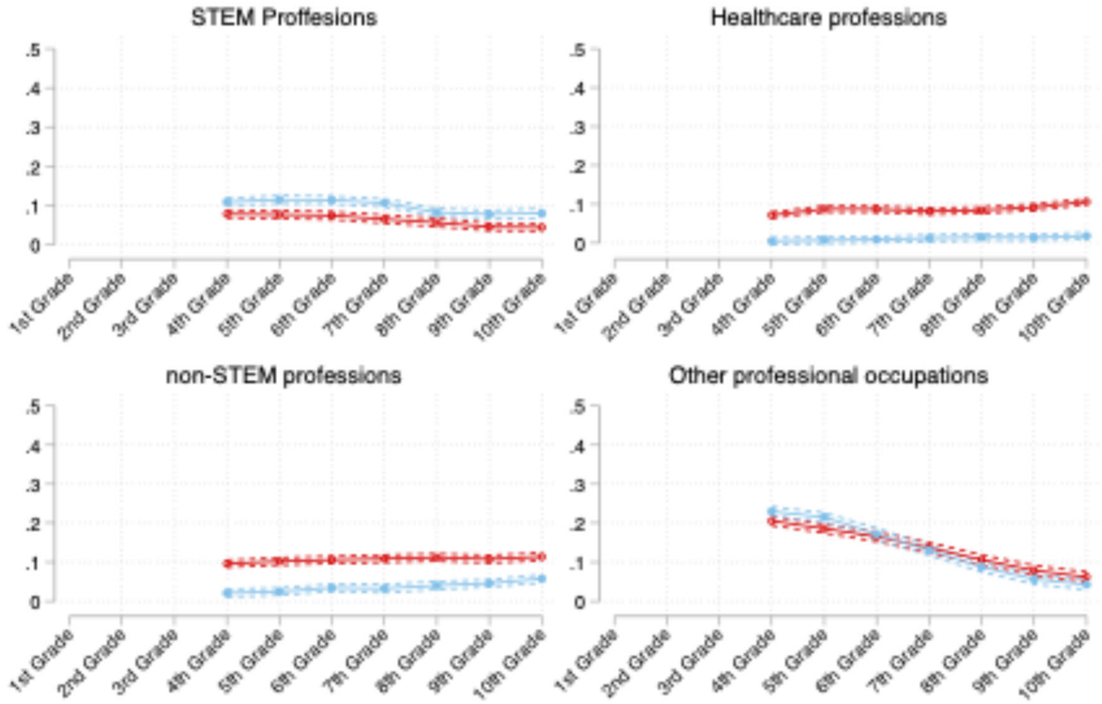
Gender disparities in occupational plans also exhibit similar trends, with gender differences in occupational plans emerging as early as the fourth grade of elementary school and persisting through the first year of high school. From the fourth grade of elementary school, males tend to express a greater inclination toward STEM professions than females do, whereas females are more inclined toward professions outside STEM fields such as healthcare and non-STEM professions than males are. This tendency is evident as early as the fourth grade of elementary school and becomes clearer as children age and start contemplating their future. These patterns remain stable without significant expansion or contraction throughout school education. These findings suggest that similar to discussions on educational disparities from socioeconomic perspectives (Downey et al., 2022), school education does not necessarily exacerbate or alleviate gender disparities, at least concerning academic self-concept, academic preference, and occupational plans, as existing gender differences are already established and maintained without significant change.

Figure 2: Changes in gender disparities in academic performance between social studies and science across grade levels



Notes: The red line represents females, whereas the blue line represents males.

Figure 3: Changes in gender disparities in occupational plans across grade levels



Notes: The red line represents females, whereas the blue line represents males.

6. Discussion and Conclusion

While there has been extensive scholarly discussion exploring the factors influencing women's lower inclination toward STEM fields than that of men, previous studies have often focused on two separate mechanisms, namely, the academic pipeline and the dream pipeline, without thoroughly discussing the relative importance of these mechanisms. Additionally, while many studies have examined whether school education functions to reduce educational disparities from a socioeconomic perspective, the discussion of gender inequality has largely overlooked whether this impact arises at the time of school entry or gradually emerges throughout school education. Given that most empirical studies focus on the United States, this study uses longitudinal data from

Japanese students ranging from the first grade of elementary school to the 3rd year of high school to examine gender inequality in STEM choices in a non-Western context and addresses the limitations of existing studies as follows.

First, I demonstrate that the academic pipeline, which is defined by academic self-concepts and academic preferences in subjects such as language, mathematics, social studies, and science, is more important than the dream pipeline, which is characterized by occupational plans, in explaining gender inequality in STEM fields in Japan. The effects of gender on enrollment in a STEM discipline can be attributed to 20% of academic self-concepts, 33% of academic preferences, and 9% of occupational plans. In contrast to studies emphasizing the importance of the dream pipeline in the United States (Morgan et al., 2013; Weeden et al., 2020), occupational plans show limited explanatory power in the Japanese context. As noted by Morgan et al. (2013), research focusing on occupational plans is scarce, especially outside the United States. Nevertheless, this study reveals that the dream pipeline may not be crucial as an explanatory factor. Furthermore, while my findings can explain approximately 40% of the gender inequality in STEM choices, the remaining 60% cannot be accounted for by the examined theoretical factors. These results suggest that factors that extend beyond subjective academic ability and occupational plans significantly contribute to gender inequality.

Second, rather than widening throughout school life, gender disparities are already present in the first grade of elementary school and remain consistent. From the first grade onward, females tend to have greater academic self-concepts and preferences in language than males do. These gender differences persist throughout school education, influencing women to choose non-STEM fields. In contrast to language, there is almost no gender difference present in academic self-concepts in mathematics, social studies, or science, suggesting that being female does not necessarily lead to an underestimation of one's own abilities in these subjects. However, gender differences do emerge in terms of academic preferences, with females being less likely than males to prefer mathematics, social studies, and science. These results imply that focusing solely on mathematics without considering the multidimensionality of the curriculum may overlook the mechanisms contributing to gender inequality in STEM choices. Similar patterns are observed for occupational plans; i.e., from the fourth grade of elementary school onward, males tend to aspire more to STEM-related professions, whereas females lean toward non-STEM fields.

The results of this paper, which focuses on a non-Western context to discuss gender inequality in STEM choices, suggest two important implications. The first implication is that the mechanism behind gender disparities in STEM choices is embedded in the social context. In Japan, high school students need to begin preparing for university entrance exams by choosing their major fields of study quite early. Therefore, the early selection of academic paths may amplify the relative importance of the academic pipeline because high school students encounter challenges in contemplating their future occupational plans. This contrasts with some previous studies that have focused on the United States and highlighted the significance of the dream pipeline (Morgan et al., 2013; Weeden et al., 2020). As noted by Riegle-Crumb et al. (2012), addressing the structural factors that generate gender inequality is fundamentally more important, despite the frequent policy implications regarding the importance of promoting entry into science-related careers (Weisgram & Dielman, 2017; Weeden et al., 2020). When considering Japan's context, the issue lies in the entrance examination system, which necessitates proficiency in mathematics for admission to STEM departments; this implies that the examination methods themselves contribute to gender inequality. Expanding avenues that extend beyond standardized tests, such as interviews and recommendation-based admissions, may be significantly more crucial in increasing the number of women majoring in STEM fields. It is important to identify the social structures that contribute to gender inequality in this way.

The second important implication is that gender disparities are neither created nor amplified by schools but are instead already present at the time of school entry. Research focusing on internal school mechanisms often argues that interactions with teachers and peers contribute to widening gender disparities (Raabe et al., 2019). Indeed, in terms of academic preference for mathematics, the relatively small gender gap in the first grade of elementary school expands by the second grade, suggesting that internal school interactions play an important role. However, the gender differences in academic self-concept and preference, as well as in occupational plans, are largely present from the early stages of school education. These results suggest that similar to the consensus in existing research that has addressed educational disparities from a socioeconomic perspective (Downey et al., 2022; Von Hippel et al., 2018), a significant portion of educational disparities arise before school entry. Without a focus on the period before children enter school, it is impossible to understand the mechanisms that generate gender inequality. This highlights the need to examine the early childhood factors that contribute to the formation of gender disparities.

Although this paper presents the abovementioned implications, it is also important to acknowledge its limitations. First, it remains unclear how the remaining 60% that cannot be explained by the academic pipeline or the dream pipeline emerged. Since microlevel variables within schools, such as the influence of teachers and peers or the classroom atmosphere, were not available, further investigations, including theoretical considerations, are needed. Second, while it has been confirmed that a large portion of the gender gap exists before the child enters elementary school, how this gap arises is not entirely clear. This is also due to the lack of available variables related to the first limitation. Future research should focus on early childhood, i.e., long before university begins. Early childhood toys and peer relationships might contribute to the gender gap in academic self-concept and academic preference. Despite these limitations, this paper makes a significant contribution by discussing the mechanisms through which gender inequality in STEM choices arises in a non-Western context. Further research should include cases from other countries to obtain a more comprehensive understanding.

Notes

1. In schools where most students aspire to employment after high school graduation, there may not be a systematized course division. However, in Japan, depending on the faculty one wishes to enter, the number of required entrance exam subjects varies. Therefore, if one hopes to advance to university, one must effectively choose between a non-STEM track and a STEM track and prepare accordingly, irrespective of whether the school has internal course divisions. While the timing of course divisions also varies by school, subjects such as mathematics and science are compulsory until the first year of high school, thereby making the factors present during this period essentially determinants of one's specialization field.
2. From first grade to third grade in elementary school, some children find reading and writing difficult. Therefore, in this survey, parents provide proxy responses while listening to their children. As a result, children's responses begin in the fourth grade of elementary school.
3. The Benesse Corporation is a leading company in the sale of educational materials, possessing vast amounts of personal information data on children who purchase their educational products. In addition, by recruiting a large-scale survey panel targeting 154,000 pairs, they successfully constructed a survey panel covering more than half of Japan's total child population. While not a completely random sample, this survey panel effectively represents children nationwide. By allocating children's gender and residential areas and extracting data,

longitudinal data on parent–child pairs can be obtained with minimal bias.

4. The graduation survey was conducted annually in March, i.e., when high school students graduate, from 2018 (wave 3) to 2022 (wave 7), except for 2020 (wave 6) when it was skipped due to the impact of the COVID-19 pandemic. Essentially, the survey targeted all third-year high school students who were being tracked in the related longitudinal study. The response rates were 69.6% in 2018, 67.9% in 2019, 68.4% in 2021, and 66.6% in 2022, totaling 3,866 students whose postgraduate pathways could be verified.
5. STEM professions are defined from 19 specialized occupations related to the following natural sciences; agricultural, forestry, fisheries, and food technology; and electrical and telecommunications engineers. Health care professionals are defined as belonging to 14 specialized occupations related to medicine, including pharmacists, public health nurses, and registered nurses. Non-STEM professions are defined as belonging to 23 specialized occupations related to education and law, such as childcare workers, school teachers, and lawyers. However, as Table 1 shows, 54.3% of high school students do not have a clear occupational plan.

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