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Gender Gaps in STEM Higher Education: Trends and the Role of Learning Modalities in Chile

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Abstract

Historically, women's participation in higher education has been shaped by traditional social roles. Although gender parity has improved in several academic fields, significant disparities persist in science, technology, engineering, and mathematics (STEM). In Chile, first-year enrollment in STEM programs increased by 37.7% between 2011 and 2024, alongside the expansion of online and hybrid learning modalities. This study analyzes the evolution of gender gaps in STEM higher education and examines whether non-traditional delivery modalities have reduced gender segregation compared with face-to-face programs. Using a quantitative, descriptive, longitudinal design, the analysis draws on public data from Chile's Higher Education Information System (SIES) covering 1,298,786 first-year students. Gender disparities are assessed using the Global Gender Gap Index and the Index of Dissimilarity, disaggregated by modality, institutional type, field of knowledge, and program level. Results show that the effects of online and hybrid education on gender equity are uneven. While universities and post-bachelor programs display higher female participation in online formats, pronounced gender gaps persist in the most populated STEM fields and in technical-professional institutions. Overall, flexible modalities support equity in specific contexts but do not constitute a structural solution to gender segregation in STEM.

Keywords: Gender equity in STEM; Higher education; Online and hybrid learning; Enrollment trends; Women in STEM; Chile.

Introduction

Importance of Reducing the Gender Gap in STEM Fields

Gender segregation in education and professional careers, particularly in STEM fields, is widely documented. This phenomenon refers to the tendency for women and men to concentrate in different fields due to structural and cultural factors that limit equitable access to economic opportunities and professional development [1]. Prior research highlights how the perception of certain fields as "masculine" strongly influences early educational choices, thereby reinforcing horizontal segregation within STEM disciplines [2].

Reducing this disparity goes beyond social justice considerations. An OECD (Organisation for Economic Co-operation and Development) report [3] underscores that women's inclusion in STEM promotes equity, enhances economic productivity and innovation capacity, and improves social conditions for historically underrepresented groups. From a macroeconomic perspective, estimates from the European Institute for Gender Equality [4] suggest that closing the gender gap in STEM could lead to substantial gains in productivity and economic growth. Although these projections are largely based on developed economies, available evidence indicates that in regions such as Latin America, characterized by deep social inequalities and a persistent gender digital divide, the costs of maintaining these gaps may be even higher, constraining both economic development and women's educational and labor opportunities [5]. In this context, advancing greater inclusion of women in STEM becomes strategically relevant to the region's sustainable development.

The social impact of the gender gap in STEM extends beyond the educational sphere and is reflected in persistent inequalities in employment, income, and social mobility. Accordingly, understanding how these gaps are shaped and identifying factors that may contribute to their mitigation, particularly from the perspective of higher education, is essential for advancing toward more equitable and sustainable systems.

The Impact of Online Education on the Gender Gap in STEM Fields

Women frequently face greater barriers to reconciling academic studies with family, work, and caregiving responsibilities. This has motivated growing interest in examining whether online and blended learning modalities may function as mechanisms that support women's participation in STEM fields. From this perspective, distance education is often presented as an alternative that may expand access by offering greater temporal and spatial flexibility compared to traditional face-to-face instruction. In this regard, international evidence suggests that online learning does not systematically disadvantage women in terms of performance, motivation, or satisfaction, and may even be associated with more positive learning attitudes in certain contexts [6].

However, the international literature presents mixed findings regarding the impact of online education on reducing the gender gap in STEM. Some studies indicate that virtual learning, by itself, does not reverse existing patterns of gender segregation, as women remain underrepresented in STEM courses and programs delivered online, particularly in large-scale contexts such as MOOCs (Massive Open Online Courses), where psychological and sociocultural barriers linked to gender stereotypes and academic identity threats continue to operate [1]. In addition, research on distance education has shown that, in certain contexts, women may exhibit lower academic outcomes than their male counterparts, especially when factors such as age, workload, and family and caregiving responsibilities intersect [7].

In contrast, other studies argue that virtual learning environments can foster women's participation when they incorporate appropriate pedagogical strategies, such as social scaffolding, virtual mentoring, and inclusive instructional design. Recent research highlights that women's learning experiences, engagement, and persistence in online contexts can improve when meaningful interactions, academic support, and gender-sensitive designs are present [8]. Similarly, evidence suggests that social and family contexts, as well as more egalitarian gender norms, may help reduce gender gaps in effort-related outcomes and participation in online learning environments [9].

Taken together, these studies indicate that the relationship between educational modality and the gender gap in STEM is complex and highly context-dependent, shaped by institutional settings, program level, and the design of the learning experience. Nevertheless, much of the existing literature focuses on course- or program-level analyses, primarily in developed countries, and provides limited evidence of a systemic, longitudinal perspective disaggregated by institutional type and disciplinary area, particularly in the Latin American context [1], [6], [9]. This gap is especially salient in highly segmented higher education systems, such as Chile's, where educational trajectories and access opportunities differ substantially across universities, professional institutes, and technical training centers.

Development of Blended and Online Education in Chile

In line with international evidence emphasizing the contextual nature of online education's impact on the gender gap in STEM, it is pertinent to situate this analysis within Chile's higher education system. Over the past decade, Chile has experienced a rapid expansion in the provision of blended and online programs, giving rise to a process of virtualization that has significantly transformed higher education trajectories, particularly in professional and technological fields [10]. Recent national studies have further shown that student outcomes and retention in online programs depend on a combination of individual and institutional factors, including gender, age, program type, and territorial location, reinforcing the need for analyses that move beyond isolated cases and adopt a systemic perspective [11]. In this context, examining trends in program offerings and enrollment in STEM programs delivered through blended and online modalities allows for an assessment of the actual scope of these modalities and provides essential context for the empirical analyses conducted in this study.

The first records of blended and online programs in Chile date back to 2011, when an initial offering of six academic programs enrolled 126 students, representing 0.2% of total first-year enrollment in STEM-related higher education programs. Since then, participation in these modalities has grown steadily, reaching 179 programs and 17,893 enrolled students by 2024, accounting for 16.6% of total first-year enrollment in STEM-related programs [12]. The evolution of first-year student enrollment in blended and online programs, disaggregated by subfield of knowledge, is presented in Table 1.

Table 1. Number of first-year students enrolled in blended or online programs by year and subfield of study. Source: SIES, 2024.

CINE-F 1997 SUBAREA	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Architecture and Construction	13	8		30	10	26	31	130	205	251	384	483	693	1,878
Physical Sciences													216	199
Industry and Production	14	50	87	8	13	56	177	228	258	243	503	624	1.487	2,001
Computer Science	83	84	249	423	788	849	1,287	1,274	1,360	1,253	2,406	3,236	4,581	5,424
Engineering and Related Professions	16	22	15	119	122	487	759	1,529	2,432	2,595	4,818	5,206	6,577	7,470
Mathematics and Statistics							10	31	18	71	170	348	396	921
Total	126	164	351	580	933	1,418	2,264	3,192	4,273	4,413	8,281	9,897	13,950	17,893
% of Students*	0.2%	0.2%	0.4%	0.6%	1.0%	1.5%	2.5%	3.5%	4.6%	5.2%	9.4%	10.9%	13.7%	16.6%

*Percentage of representation of first-year students enrolled in blended and online modalities relative to the total number of first-year students enrolled in STEM programs.

The information in Table 1 shows sustained, accelerated growth in first-year student enrollment in STEM programs delivered through blended and online modalities over the analyzed period. This growth has been driven primarily by the expansion of fully online programs, which account for the largest share of total enrollment. In 2024, 89.4% of first-year students enrolled in these modalities were registered in online programs, while 10.6% were enrolled in blended programs. This trend highlights the increasingly prominent role of online education in STEM training and provides essential context for the subsequent analyses conducted in this study.

To complement the description of enrollment trends in STEM programs offered through blended and online modalities, it is also relevant to examine the relative distribution of first-year students by modality across the analyzed period. This approach allows for an assessment of the growing weight of each modality within the system and helps to contextualize the subsequent analysis of the gender gap (Fig. 1).

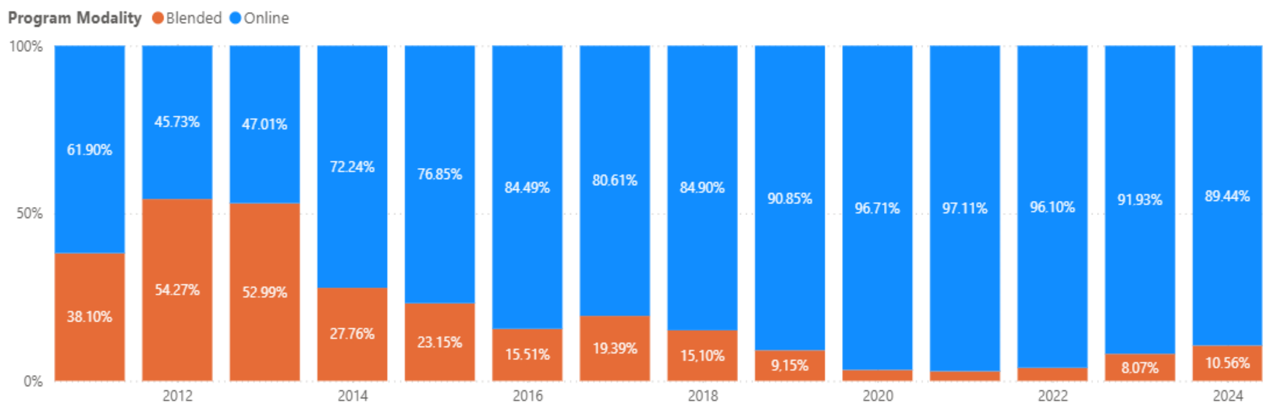

Figure 1. Distribution of first-year students enrolled in blended and online programs, 2011–2024. Source: SIES, 2024.

Figure 1 reveals a structural change in the composition of first-year enrollment in STEM programs, characterized by a sustained increase in the share of online education at the expense of blended modalities. From the mid-2010s onward, online programs account for a growing proportion of enrolled students, reaching 89.4% of total enrollment in these modalities by 2024. This trend reflects the consolidation of online education as a viable pathway to STEM training and underscores the need to examine its implications for gender equity.

Within this context, the present study aims to analyze the gender gap in STEM fields in Chile by assessing whether blended and online modalities have acted as catalysts for equity or, conversely, have reproduced the patterns of segregation observed in face-to-face education. To this end, the study examines enrollment distributions from a disaggregated perspective by type of institution, field of knowledge, and educational level (undergraduate and postgraduate), providing empirical evidence to better understand this phenomenon within a highly segmented higher education system.

Methodology

This research adopts an exploratory quantitative design to analyze the impact of the availability of blended and online study modalities on the participation of female students in STEM programs within the Chilean higher education system. Gender gap indicators focus on the number of women enrolled in STEM programs in the first year, from 2011 to 2024. The analysis seeks to determine whether inclusion patterns differ across face-to-face, blended, and online modalities through comparative assessment.

The dataset was obtained from the Higher Education Information System (Sistema de Educación Superior, SIES), a public database that provides comprehensive information on Chilean higher education institutions. The analysis includes 53 technical training centers, 21 professional institutes, and 60 universities, totaling n = 1,272,237 first-year STEM students enrolled between 2011 and 2024. The distribution of students by institution type, program modality, field of knowledge, gender, and program level (undergraduate, post-bachelor, and postgraduate) is presented in Table 2.

Table 2. Number of first-year students by type of institution and program level (2011–2024).

	Technical Training Centers	Professional Institutes		Universities			% students
	Undergraduate	Undergraduate	Post-bachelor	Undergraduate	Post-bachelor	Graduate	
Architecture and Construction	39,347	109,787		85,588	2,043	3,085	18.85%
Physical Sciences	4,730	4,977		49,005	373	3,394	4.91%
Industry and Production	12,107	34,785		36,949	601	693	6.69%
Computer Science	33,181	117,767	59	71,203	4,263	3,009	18.04%
Engineering and Related Professions	144,989	214,970		269,260	3,028	9,133	50.41%
Mathematics and Statistics	10	651		7,494	3,358	2,398	1.09%
Total	234,364	482,937	59	519,499	13,666	21,712	100.00%

Data analysis

For data analysis, gender inequality indicators were employed, specifically the GGGI (Global Gender Gap Index). This index is appropriate for the present study because it provides a synthetic representation of the relationship between female and male enrollment in STEM programs, facilitating comparisons across different institutional and temporal contexts. For its calculation, administrative data from the Higher Education Information System (SIES) were used, considering first-year student enrollment disaggregated by year, study modality (face-to-face, blended, and online), type of institution, field of knowledge, and educational level.

The analysis was conducted from a descriptive and longitudinal perspective, examining the evolution of the index over the 2011–2024 period. Index values were analyzed across modalities and institutional types to identify patterns of underrepresentation, parity, or overrepresentation of women in STEM programs. Given the aggregated nature of the data, the study does not seek to establish causal relationships, but rather to describe trends and structural differences in gender distribution.

The GGGI index is defined as follows:

$$Bg = \frac{\sum_k \quad m_{t,k}}{\sum_k \quad h_{t,k}}$$

Where:
- $m_{t,k}$: Total number of female students in year *t* in institution/program *k*.
- $h_{t,k}$: Total number of male students in year *t* in institution/program *k*.

The interpretation of the index is as follows:
- $0 \leq B_g < 1$: Female underrepresentation
- $B_g = 1$: Gender parity
- $B_g > 1$: Female overrepresentation

Results

Analysis by field of knowledge

Figure 2 examines the distribution of the GGGI index over the period 2011–2024 by field of knowledge and mode of delivery, revealing heterogeneous patterns across disciplines. The boxplot analysis allows for the identification of three distinct groups of results.

The first group comprises fields in which the availability of online or blended programs appears to favor female participation compared to face-to-face programs (Physical Sciences; Industry and Production). A second group includes fields in which the GGGI index indicates similar levels of female participation across the three delivery modalities (Computer Science, Mathematics, and Statistics). Finally, a third group, comprising three fields of study, shows that the delivery of programs in blended and online modalities has not favored women's participation relative to face-to-face education.

Regarding differences by delivery modality, face-to-face programs exhibit a higher concentration of observations along with greater dispersion in index values. In contrast, online and blended modalities display minimal variability in their results.

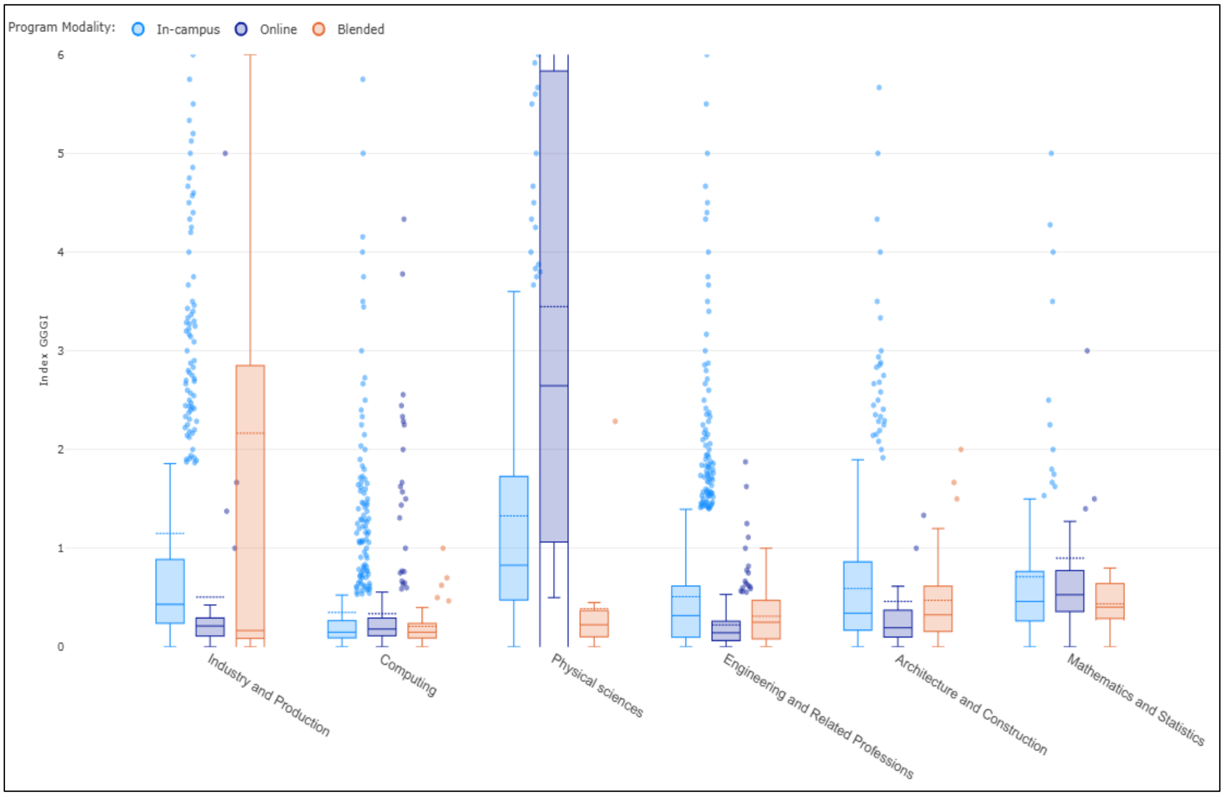

Figure 2. Boxplot of GGGI index values for first-year enrolled students, distributed by mode of delivery and field of knowledge, 2011–2024. Source: SIES, 2024 [11].

Complementing the previous analysis, the bars in Figure 3 display the GGGI index values for 2024, broken down by mode of delivery and field of knowledge, while the line graph shows the percentage of students relative to the total number of first-year STEM students enrolled.

The figure reveals a critical inverse correlation between enrollment massification and gender equity. The most populous fields, Engineering and Computer Science, which together account for 73% of total enrollment, exhibit the lowest GGGI index values. These indices range between 0.21 and 0.36, values close to zero that indicate extremely low female participation and severe masculinization, regardless of whether the programs are delivered in face-to-face or online modalities.

In contrast, gender equity appears to be concentrated in specific academic niches. Industry and Production (face-to-face) stands out as a successful case, with a GGGI value of 1.06, reflecting perfect gender parity. Even more striking are Physical Sciences (online), with an index of 4.43, and Mathematics and Statistics (online), with a value of 1.34, indicating that in these pure science formats, female participation is not only high but substantially exceeds parity benchmarks.

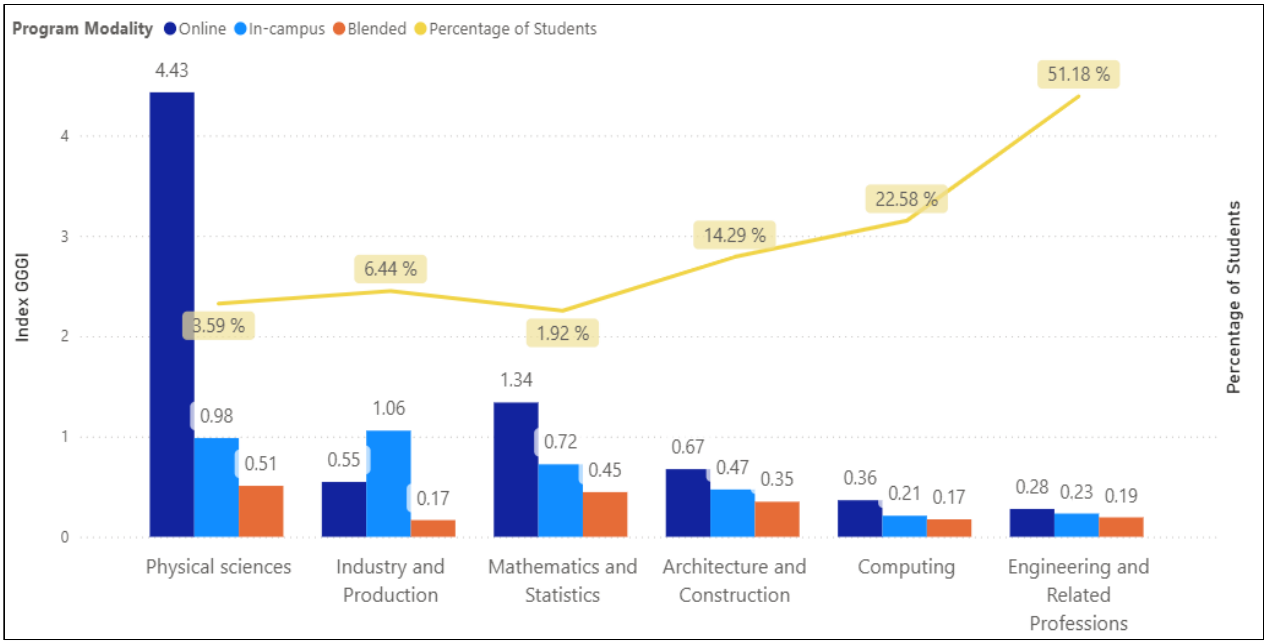

Figure 3. GGGI index values for newly enrolled first-year students in 2024, distributed by mode of delivery and field of knowledge. Source: SIES, 2024 [11].

Analysis by type of institution

The distribution of the GGGI index by type of institution (Technical Training Centers [CFT], Professional Institutes [IP], and Universities) and by mode of delivery over the 2014–2025 period is illustrated in Figure 4. The figure shows that face-to-face education predominates in terms of student numbers and, across all institutional types, exhibits both a higher average GGGI value and greater dispersion in the results.

When comparing institutions, a clear structural distinction emerges:

a) Technical sector (Technical Training Centers – CFT and Professional Institutes – IP): Online and blended modalities exhibit extremely compact and homogeneous behavior, with GGGI index values close to zero and very low variability. In contrast, within these institutions, face-to-face programs display greater variation in results.

b) Universities: Universities present a more robust structure. Their boxplots are taller and wider, indicating higher average GGGI values than those observed in the technical sector. Even face-to-face programs show greater dispersion and range—reaching index values as high as 6—suggesting a more heterogeneous distance education offer and higher performance ceilings than those observed in professional institutes.

Figure 5 examines the relationship between the GGGI index and the distribution of student enrollment across the higher education system, disaggregating by institution type (Universities, Professional Institutes, and Technical Training Centers) and mode of delivery (online, face-to-face, and blended). The figure reveals pronounced inequalities depending on both institutional type and educational modality.

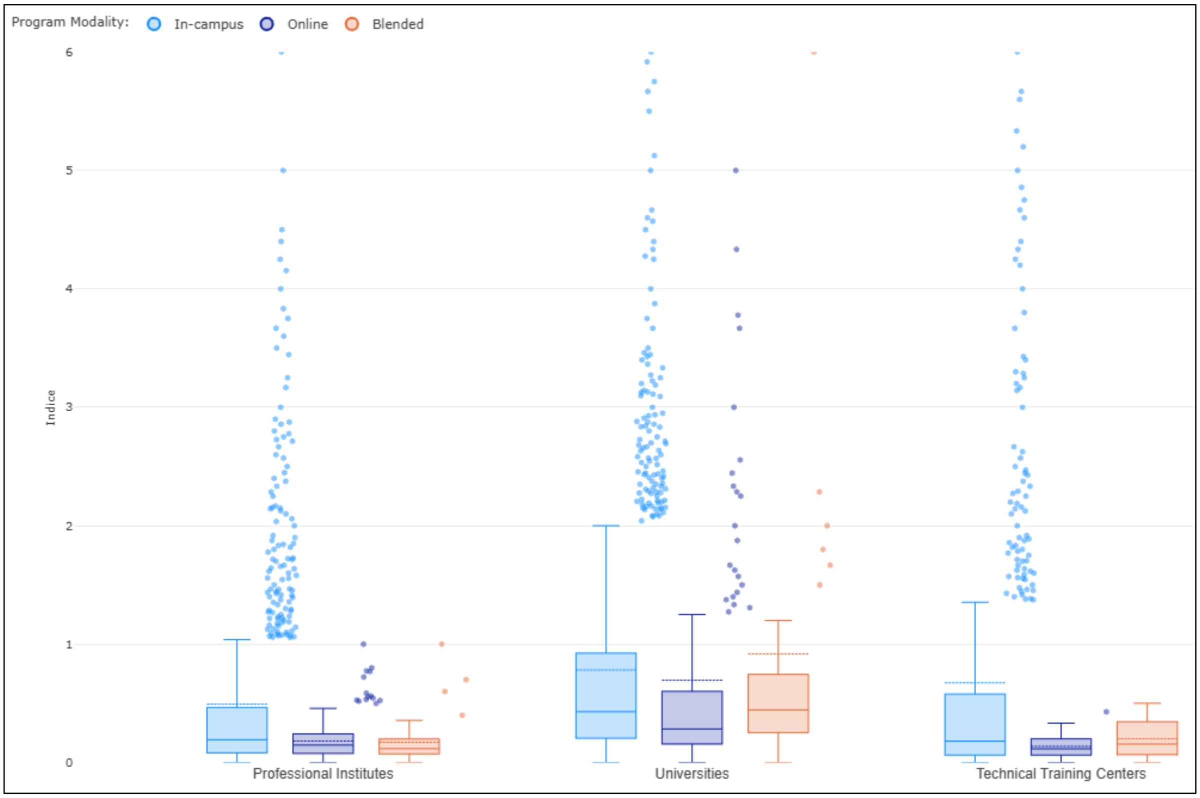

Figure 4. Boxplot of GGGI index values for first-year enrolled students, distributed by mode of delivery and type of institution, 2011–2024. Source: SIES, 2024 [11].

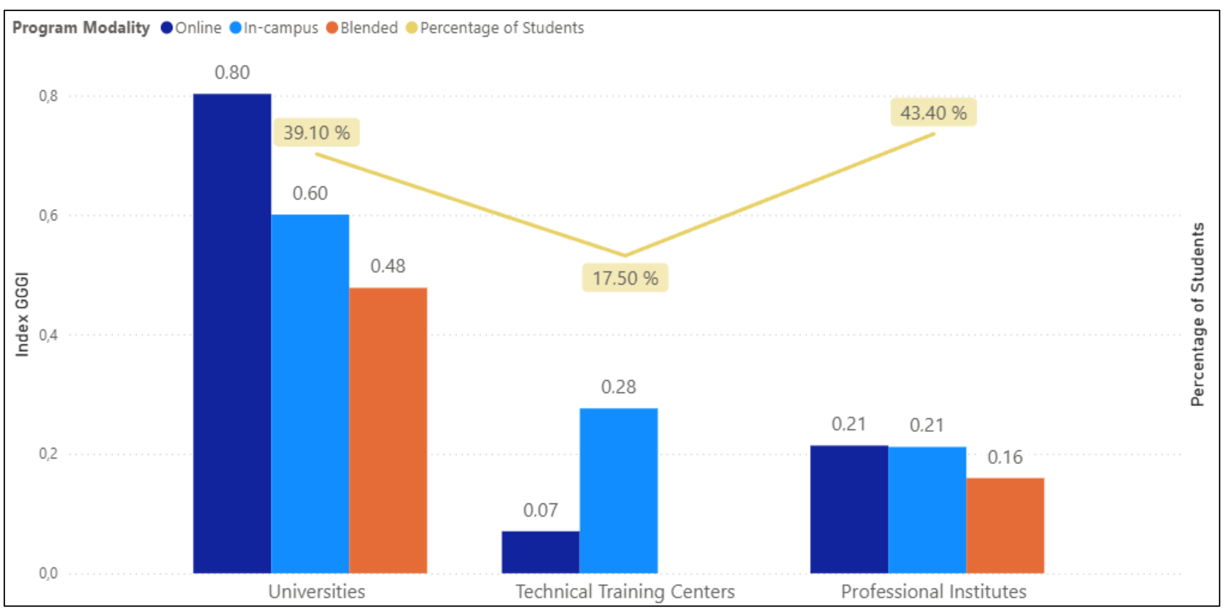

Figure 5. GGGI index values for newly enrolled first-year students in 2024, distributed by mode of delivery and type of institution. Source: SIES, 2024 [11].

The highest level of female participation is observed in universities, with particularly strong results in the online modality, reaching a GGGI index of 0.80. This value exceeds those observed in face-to-face (0.60) and blended (0.48) modalities. In contrast, Professional Institutes (IP) represent the most populous segment of the system, enrolling 43.40% of total students; however, this massification is not reflected in female participation. GGGI index values in this sector are consistently low and flat, with both online and face-to-face modalities registering 0.21, while the blended modality decreases further to 0.16.

Finally, Technical Training Centers (CFT), which account for 17.50% of total enrollment, exhibit the greatest variation in gender distribution across program modalities. In this segment, face-to-face programs reach a modest GGGI value of 0.28, whereas online programs show extremely low female participation, with an index value of 0.07.

Analysis by program level

Figure 6 presents a boxplot of the GGGI (2014–2024), disaggregated by academic level (postgraduate, post-bachelor, and undergraduate) and mode of delivery (online, face-to-face, and blended). Across all three academic levels, face-to-face programs exhibit greater dispersion and variability in GGGI values, reaching the highest index levels. This pattern is particularly pronounced in face-to-face undergraduate programs.

Unlike the other groups, this segment displays an extreme duality: a low median similar to that of the remaining categories, combined with a dense vertical column of outlier values extending up to index values of 6. This indicates that, although the average GGGI for face-to-face undergraduate programs is low, there exists a substantial subgroup of programs that achieve the highest performance levels observed in the entire sample, a phenomenon that is not replicated to the same extent in postgraduate or post-bachelor programs.

In contrast, online and blended modalities exhibit much more homogeneous, compact distributions (small boxplots), with most values concentrated in the lower range of the graph (between 0 and 1). This pattern suggests more standardized processes, but with fewer cases of exceptionally high scores.

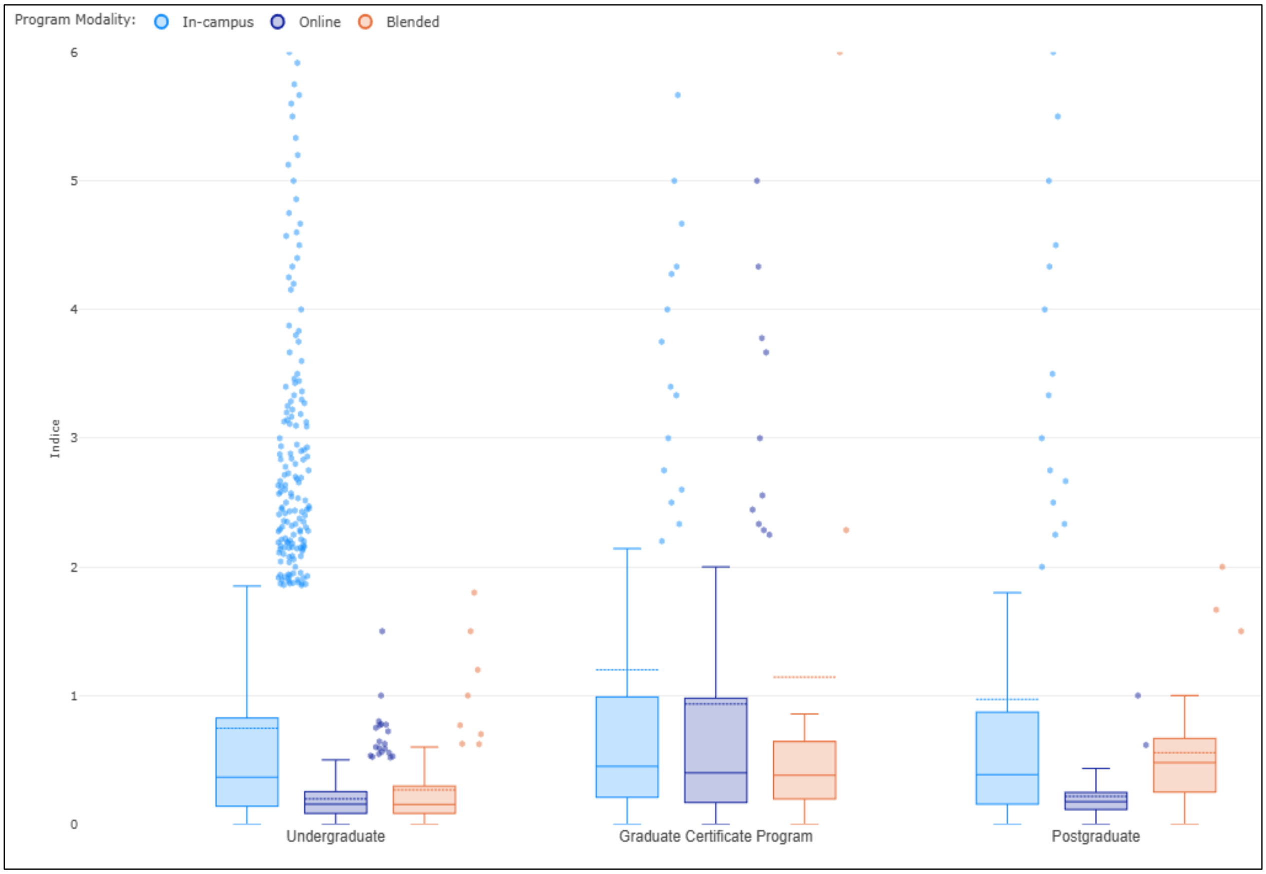

Figure 6. Boxplot of GGGI index values for first-year enrolled students, distributed by mode of delivery and program level, 2011–2024. Source: SIES, 2024 [11].

Figure 6 illustrates the relationship between the GGGI index and the distribution of student enrollment across the higher education system, disaggregated by program level and mode of delivery. The figure shows that undergraduate programs account for the vast majority of students (94.53% of total enrollment) and simultaneously exhibit the highest levels of gender inequality, with minimal GGGI values across delivery modalities: face-to-face (0.32), blended (0.27), and online (0.23).

In contrast, post-bachelor programs, which represent 3.32% of total enrollment, achieve the most favorable results in the figure. At this level, face-to-face programs display higher female than male participation, with a GGGI value of 1.23, exceeding the gender parity threshold, while the online modality reaches a robust value of 0.97. This suggests that short-cycle specialization programs constitute the most inclusive and balanced segment of the system; however, their overall social impact remains limited due to their relatively low enrollment.

Finally, postgraduate programs, which account for 2.15% of total enrollment, show variation depending on delivery format. While face-to-face postgraduate programs exhibit a GGGI index value of 0.71, distance education formats reflect lower female participation, as indicated by the online (0.27) and blended (0.28) modalities.

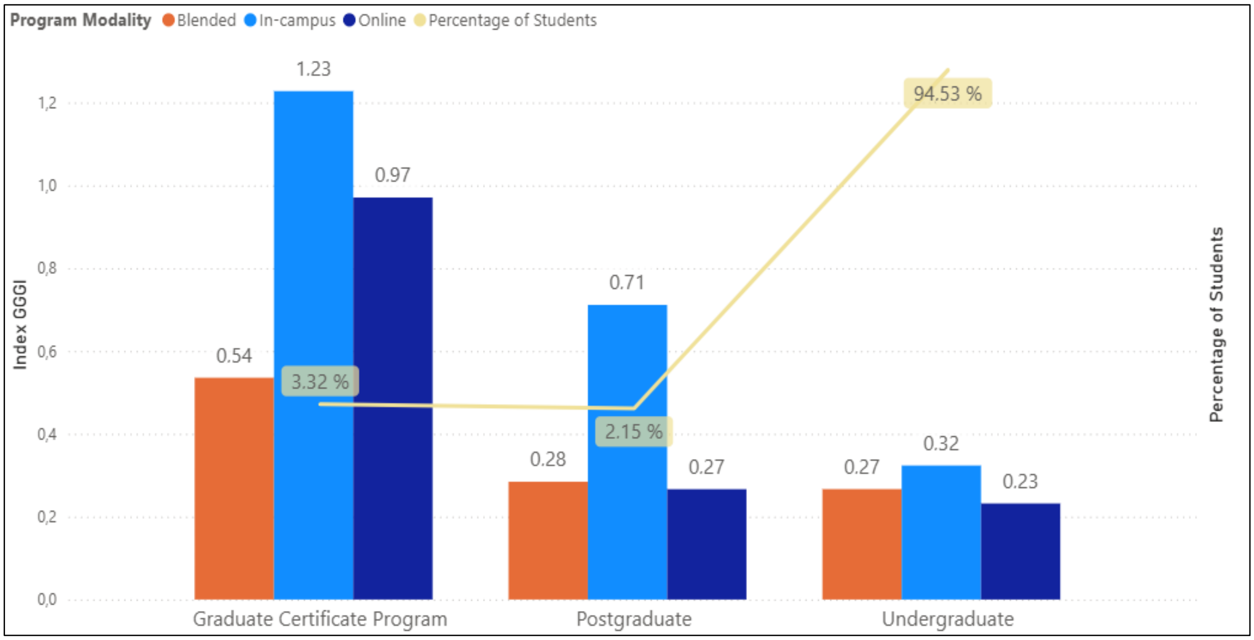

Figure 7. GGGI index values for newly enrolled first-year students in 2024, distributed by mode of delivery and program level. Source: SIES, 2024 [11].

Discussion

This study analyzed the gender gap in STEM fields within the Chilean higher education system, with the aim of examining whether the expansion of blended and online programs has contributed to reducing, maintaining, or deepening the patterns of gender segregation historically observed in face-to-face education. To this end, an exploratory quantitative study was conducted, based on a descriptive, longitudinal analysis of administrative data from the Higher Education Information System (SIES) covering first-year student enrollment from 2011 to 2024. The analysis relied on gender inequality indicators, primarily the Global Gender Gap Index and the dissimilarity index, while accounting for differences by program modality, type of institution, field of knowledge, and educational level. From this perspective, the discussion focuses on interpreting the observed patterns and critically examining the role of virtual education as a potential mechanism for gender equity in highly segmented STEM contexts such as Chile.

Educational modality and the gender gap: differentiated effects of virtuality. One of the central findings of this study is that the impact of blended and online modalities on the gender gap in STEM is not uniform but varies significantly across institution types and program levels. The results show that, within universities and post-bachelor programs, the online modality is associated with indicators closer to gender parity, even surpassing those observed in face-to-face education, favoring women's participation and learning processes, in line with the findings reported by Yu and Deng [6]. In contrast, in professional institutes and technical training centers, virtual education appears to function as a neutral or even unfavorable factor for female participation. This evidence, consistent with previous studies [1], suggests that technology alone is insufficient to overcome vocational, cultural, and structural barriers embedded in certain segments of the system, reinforcing the need to conceptualize virtual education as a context-dependent enabler rather than an inherently equitable solution.

Massification, exclusion, and the persistence of segregation in STEM fields. A second axis of discussion concerns the paradox between the massification of certain STEM fields and the levels of gender equity achieved. The results are consistent with prior research [13], which indicates that fields with the highest enrollment volumes, such as Engineering, Computer Science, and related professions, concentrate the majority of students while exhibiting the lowest gender equity index values, regardless of the mode of delivery. This pattern highlights that online education has not substantially altered the structure of gender segregation in the most populous fields of the system. Conversely, cases in which parity or overrepresentation of women is observed tend to be concentrated in specific academic niches or in specialized program levels with relatively low enrollment shares, limiting their systemic impact and raising questions about the capacity of virtual education to promote structural transformation in mainstream undergraduate STEM education.

Institutional segmentation and asymmetries in the impact of virtual education. The results further reveal that, as in face-to-face education [14], there are clear asymmetries in the impact of virtual education across institutional types, reflecting the structural segmentation of the Chilean higher education system. While universities exhibit higher levels of female participation in online programs and greater variability in gender equity indicators, professional institutes and technical training centers exhibit more homogeneous, persistently low patterns. This disparity suggests that institutional conditions, such as academic offerings, the social prestige of programs, prior educational trajectories, and associated labor market expectations, play a decisive role in shaping how educational modality interacts with the gender gap. From this perspective, virtual education may expand opportunities in institutional contexts with higher academic capital, while reproducing inequalities when embedded in highly segregated training structures.

Taken together, these patterns invite a broader interpretation beyond modality effects alone. The differentiated impact of online and blended modalities on gender equity in STEM may be shaped by a set of structural and contextual mechanisms that cannot be directly observed in the available administrative data. These patterns are likely influenced by factors such as temporal flexibility and life-course stage, particularly in post-bachelor programs, where online formats may better accommodate work, caregiving responsibilities, and non-linear educational trajectories. At the same time, institutional segmentation appears to play a critical role: universities, which typically offer programs with higher social prestige and stronger labor-market signaling, may create conditions in which online education expands access without undermining perceived program quality, whereas technical-professional institutions may reproduce existing gender hierarchies regardless of delivery modality. From this perspective, gendered participation in online STEM programs may reflect processes of structural self-selection shaped by institutional context, program positioning, and labor market expectations, rather than individual preferences alone. These interpretations are consistent with prior research emphasizing the context-dependent nature of virtual education and caution against attributing equity outcomes solely to modality effects [1], [7]-[9].

Implications and Recommendations

The findings of this study have several implications for institutional decision-making and public policy regarding the implementation of online and blended STEM programs. First, the results indicate that online education can contribute to greater gender parity in specific contexts, particularly within universities and post-bachelor programs. In these settings, virtual modalities appear to facilitate women's participation, suggesting that institutions may leverage online formats as a strategic tool to expand access and re-entry opportunities for women in STEM, especially for students balancing academic, work, and caregiving responsibilities. However, these potential benefits are not automatic and should be intentionally aligned with equity-oriented institutional goals rather than assumed as an inherent outcome of modality change.

Second, the consistently low levels of female participation observed in professional institutes and technical training centers highlight the limitations of online education as a standalone mechanism for reducing gender segregation. In highly segmented technical-professional contexts, expanding online programs without complementary institutional strategies may reproduce existing inequalities. These findings suggest that institutions in this sector should consider integrating online delivery with targeted support measures, such as academic guidance, outreach initiatives, and alignment with labor market expectations, to prevent virtual education from reinforcing established patterns of exclusion.

Third, from a system-level and policy perspective, the persistent concentration of gender equity in small academic niches and less populated program levels underscores the need for differentiated approaches across fields of knowledge and institutional types. The results indicate that equity gains achieved in specific segments, such as online programs in Physical Sciences or post-bachelor education, have a limited impact on the overall system due to their low enrollment shares. Consequently, public policies aimed at reducing the gender gap in STEM should avoid treating online education as a universal solution and instead promote coordinated strategies that address structural segmentation, recruitment practices, and program positioning within the most massified STEM fields.

Conclusions

This study examined the evolution of the gender gap in STEM fields within the Chilean higher education system between 2011 and 2024, focusing on the role of blended and online modalities from a longitudinal and system-level perspective. The findings indicate that, while online and blended education are associated with reductions in the gender gap compared to face-to-face programs, these effects are highly uneven across institutional types, educational levels, and fields of knowledge, reflecting the persistence of structural inequalities in women's participation in STEM.

Overall, online education shows a differentiated impact depending on institutional context. In universities, particularly at the post-bachelor level, online programs are associated with levels of gender parity closer to those observed in face-to-face education, and in some cases, exceed them.

In contrast, in professional institutes and technical training centers, virtual education does not appear to significantly reduce the gender gap and may even be associated with lower female participation. These results suggest that expanding flexible modalities alone is insufficient to overcome the vocational, cultural, and structural barriers to women's participation in technical STEM education.

In addition, the analysis by field of knowledge reveals a persistent paradox between massification and equity. STEM fields with the highest enrollment volumes, such as Engineering and Computer Science, continue to exhibit the lowest levels of gender equity regardless of delivery modality, while parity or female overrepresentation is concentrated in smaller academic niches or specific program levels with limited systemic impact.

From a policy perspective, these findings highlight that the contribution of online and blended education to gender equity in STEM is context-dependent and contingent on institutional and structural conditions. Virtual education can expand opportunities in certain settings but is unlikely to generate structural change without explicit institutional strategies and public policies to address gender segregation, particularly within the technical-professional sector. Finally, this study provides empirical evidence to inform future research on educational trajectories, institutional practices, and differentiated policy approaches needed to advance gender equity in STEM beyond mere online education expansion.

A key limitation of this study is its focus on first-year enrollment data, which prevents analysis of gender differences in persistence, progression, or completion in STEM programs. In addition, the administrative nature of the data precludes direct examination of individual motivations, decision-making processes, or experiential factors that may influence enrollment choices across modalities. Future research should therefore incorporate longitudinal student-level data, where available, to examine whether the observed patterns of access are sustained over time, as well as complementary approaches, such as surveys or mixed-method designs, to explore gender-differentiated motivations, trajectories, and persistence in STEM across face-to-face, blended, and online programs.

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