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Educational Gender Gaps in Bogotá and the Right to Education*

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Abstract

This study has three objectives. Firs, it investigates the size of the gender gaps in mathematics and natural science outcomes across localities and schools in Bogotá. Second, it examines the associations between gender gaps in these areas and indicators of availability, acceptability, and adaptability of the right to education in the city's schools. Third, it explores the independent and gender-specific associations between individual outcomes in these areas and the aforementioned right-to-education indicators. To achieve this, data from the Right to Education Index for Bogotá's public sector and the 2020 Saber 11 exam database were used. Descriptive analyses, linear regressions, and multilevel regressions were performed. The results showed that gender gaps disadvantaging women in the analysed areas are prevalent in almost all localities and schools across Bogotá. Furthermore, the findings indicated that gender gaps in these areas tend to favour women in schools with better conditions of availability, acceptability, and adaptability. However, the multilevel model results demonstrated that the acceptability and availability indicators predict better individual scores in mathematics and natural sciences, and these associations are not moderated by student gender.

Keywords

achievement gaps; gender differences; mathematics achievement; science achievement; exit examinations; right to education

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Desigualdades de gênero na educação em Bogotá e o direito à educação

Resumo

Este estudo tem três objetivos. Primeiro, investiga o tamanho das lacunas de gênero nos resultados de matemática e ciências naturais nas localidades e escolas de Bogotá. Segundo, investiga as associações entre as lacunas de gênero nessas áreas e os indicadores de disponibilidade, aceitabilidade e adaptabilidade do direito à educação nas escolas da cidade. Terceiro, examina as associações (independentes e heterogêneas de gênero) entre os resultados individuais nessas áreas e os indicadores mencionados do direito à educação. Para isso, foram utilizados os bancos de dados do Índice de Direito à Educação do setor público de Bogotá e a base de dados do exame Saber 11 do ano de 2020. Foram realizados também análises descritivas, regressões lineares e regressões multinível. Os resultados mostraram que as lacunas de gênero desfavoráveis às mulheres nas áreas analisadas são um fenômeno prevalente em quase todas as localidades e escolas da cidade de Bogotá. Além disso, os resultados indicaram que as lacunas de gênero nessas áreas tendem a ser mais favoráveis às mulheres nas escolas com melhores condições de disponibilidade, aceitabilidade e adaptabilidade. No entanto, os resultados dos modelos multiníveis mostraram que os indicadores de aceitabilidade e disponibilidade predizem melhores resultados nos escores individuais de matemática e ciências naturais, e que essas associações não são moderadas pelo gênero dos alunos.

Palavras-chave

diferenças de gênero; resultados em matemática; resultados em ciências; exames finais; direito à educação

Brechas de género educativas en Bogotá y el derecho a la educación

Resumen

Este estudio tiene tres propósitos. Primero, se investiga cuán grandes son las brechas de género en los resultados en matemáticas y ciencias naturales en las localidades y colegios de Bogotá. Segundo, se investigan las asociaciones entre las brechas de género en dichas áreas e indicadores de disponibilidad, aceptabilidad y adaptabilidad del derecho a la educación en los colegios de la ciudad. Tercero, se investigan las asociaciones (independientes y heterogéneas de género) entre los resultados individuales en dichas áreas y los indicadores anteriormente mencionados del derecho a la educación. Para ello, se usaron las bases de datos del Índice del Derecho a la Educación del sector oficial de Bogotá y la base de datos del examen Saber 11 del año 2020. Asimismo, se realizaron análisis descriptivos, regresiones lineales y regresiones multinivel. Los resultados mostraron que las brechas de género en contra de las mujeres en las áreas analizadas son un fenómeno prevalente en casi todas las localidades y colegios de la ciudad de Bogotá. Asimismo, los resultados mostraron que las brechas de género en dichas áreas tienden a ser más favorables para las mujeres en los colegios con mejores condiciones de disponibilidad, aceptabilidad y adaptabilidad. No obstante, los resultados de los modelos multinivel mostraron que los indicadores de aceptabilidad y disponibilidad predicen mejores resultados en los puntajes individuales de matemáticas y ciencias naturales, y que estas asociaciones no están moderadas por el género del estudiantado.

Palabras clave

clave diferencias de género; resultados en matemáticas; resultados en ciencias; exámenes de estado, derecho a la educación

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Introducción

The differences in academic achievement between boys and girls, usually referred to as gender gaps, are important in many countries (Laboratorio Latinoamericano de Evaluación de la Calidad de la Educación, 2021; Meinck & Brese, 2019; OECD, 2019). Nevertheless, the direction of these differences and their magnitude vary significantly between areas of knowledge and countries (Borbón Vásquez et al., 2020; Contini et al., 2017; Laboratorio Latinoamericano de Evaluación de la Calidad de la Educación, 2021; Meinck & Brese, 2019; OECD, 2019).

In Colombia, gender gaps exhibit several interesting features. First, as in many countries, Colombian girls outperform boys in reading achievement. However, Colombia has one of the smallest gender gaps in reading among the countries that participated in the Programme for International Student Assessment (pisa) in 2018 (OECD, 2019). In Colombia, girls outperformed boys in reading achievement on the PISA 2018 by 10 points, whereas across countries belonging to the Organisation for Economic Co-operation and Development (OECD) this difference was on average almost 30 points (OECD, 2019). Second, across countries that participated in OECD 2018, boys outperformed girls in mathematics achievement (OECD, 2019). Nevertheless, Colombia exhibited the largest differences between girls and boys, in favor of boys (OECD, 2019). Third, Colombia displayed one of the largest gender gaps in science achievement, favoring boys, in the PISA 2018, with a difference of 13 points (OECD, 2019). In sum, gender gaps in mathematics and science achievements, favoring boys, are more prevalent in Colombia than in other OECD countries.

Regarding gender gaps in mathematics and science in the PISA 2018 in Bogotá D.C., the capital city of Colombia, the evidence suggests that gender gaps share similar characteristics with those in the entire country. Borbón Vásquez et al. (2020) found that gender gaps in mathematics and science achievements, favoring boys, were 23 and 20 points, respectively.

Given that gender gaps in mathematics and science favor boys in Colombia and Bogotá, educational stakeholders should consider why these differences matter and why public resources should be invested in reducing them. Gender gaps in mathematics and science are significant because they reflect inequalities in the development of knowledge and skills between boys and girls in these areas. Gender gaps in mathematics and sciences favoring boys also matter because they result from traditional stereotypes about the roles of boys and girls in society that persist today (Meinck & Brese, 2019). These stereotypes influence teachers' and parents' expectations about boys' and girls' achievements, which affect the students' self-concept, academic achievement, and career choices (Meinck & Brese, 2019). This can help explain why boys tend to choose careers related to Science, Technology,

Engineering, and Mathematics (STEM) more often than girls (Dulce-Salcedo et al., 2022; Espinosa Borda et al., 2020; Gomez Soler et al., 2020; Meinck & Brese, 2019; OECD, 2019).

Gender gaps also matter because they have significant economic consequences. The academic literature has documented that reducing educational gender inequalities is associated with increased economic growth rates, as these reductions also promote improvements in overall human capital (Klasen, 2002). However, it is worth noting that this literature often relies on transnational research designs, and as a consequence, it cannot estimate causal effects, focusing instead on correlations between economic growth rates and educational gender inequalities (Bandiera & Natraj, 2013). In other words, this literature cannot definitively determine whether improvements in gender equality promote economic growth or if improvements in economic growth promote gender equality (Bandiera & Natraj, 2013). Furthermore, the estimations in this literature may be biased due to the omission of important variables that are correlated with both economic growth and gender inequality (Bandiera & Natraj, 2013).

Given the above, it is important to study the factors associated with gender gaps in mathematics and science. This research may offer insights for designing actions and strategies aimed at reducing educational gender gaps by helping girls develop their mathematics and science competencies. Likewise, these actions and strategies may create opportunities to implement experimental or quasi-experimental studies capable of estimating the causal effects of these actions and strategies on gender gaps in mathematics and science.

What Factors Explain Gender Gaps?

The factors that explain gender gaps in mathematics and natural sciences remain an open question in the national academic literature. A recent study found that only a small portion of the variance in the gender gap can be explained by individual, family, and school characteristics, such as student age, parental educational level, parental occupational status, family socioeconomic status, hours of school attendance, school location, and whether the school is public or private (Abadía & Bernal, 2017). Abadía & Bernal (2017), upon reviewing the literature on the determinants of the gender gap, state that the gender gap may be influenced by other factors, such as students' attitudes, differences in the roles played by men and women in Colombia, cultural aspects related to gender equity, and academic environments.

Two possible causes of gender gaps are students' beliefs regarding their ability to excel in mathematics and science and their emotions toward these areas of knowledge. On the one hand, evidence from PISA 2006 and 2012 shows that girls have lower levels of self-efficacy in science and mathematics than boys (OECD, 2015).

Likewise, the evidence shows a positive correlation between self-efficacy in science and mathematics and students' scores on these exams (OECD, 2015). Evidence from Colombia aligns with these findings. Prior research found that self-confidence in mathematics learning skills is one of the main predictors of the gender gap in mathematics in the Trends in International Mathematics and Science Study (TIMSS) 2007 (Correa Fonnegra, 2016). On the other hand, girls generally report higher levels of math anxiety than boys (OECD, 2015). Additionally, a recent study found that across oecd countries, anxiety towards mathematics is negatively associated with students' results in mathematics (OECD, 2015).

Other causes of the gender gap may be related to cultural and social differences across countries. Prior research has found that more progressive societies in terms of gender equity exhibit smaller differences in mathematical achievement between men and women (González de San Román & de la Rica, 2016; Guiso et al., 2008). Guiso et al. (2008) found that societies that have made more progress toward gender equity also exhibit smaller differences in mathematical achievements between boys and girls in the PISA 2003. González de San Román & de la Rica (2016) also examined the role of gender equity on gender gaps. Their results showed that improvements in gender equity were associated with smaller differences in mathematical achievements between boys and girls (González de San Román & de la Rica, 2016).

Other factors influencing the gender gaps may be related to academic environments. Previous studies have examined the influence of teachers' use of cognitive-activation strategies, assessment practices, and the alignment of teachers' and students' genders in narrowing these gaps (Day et al., 2018; Gomez Soler et al., 2020; OECD, 2015; Silva Hernández, 2020). Regarding the influence of teachers' use of cognitive-activation strategies in reducing gender gaps, a prior study found that these strategies are associated with improvements in students' mathematical skills (OECD, 2015). Likewise, in some countries, these strategies are associated with greater improvement in girls' performance than in boys' performance (OECD, 2015). Concerning assessment practices, Day et al. (2018) found that the implementation of continuous assessment (i.e., multiple assessments rather than just one final exam) was associated with smaller differences between girls and boys in a non-representative sample of undergraduate students. Regarding the influence of the alignment of teachers' and students' genders on gender gaps, prior research found that this alignment is not associated with gender gaps in 12 Latin American countries (Silva Hernández, 2020). Finally, a previous study found that attendance in an undergraduate program increases the differences in mathematical skills in favor of boys, and this increase is larger for students attending a STEM program (Gomez Soler et al., 2020).

Even though the aforementioned studies have contributed to enhancing the understanding of the determinants of gender gaps, it is important to note that there is

a lack of research investigating the role of the realization of the right-to-education in reducing gender gaps in mathematics and natural science. Similarly, it is worth noting that few studies have explored the factors associated with these gaps. Upon reviewing this literature, I identified five studies that have examined the factors associated with these gaps in mathematics and natural science (Abadía & Bernal, 2017; Correa Fonnegra, 2016; Gómez Soler et al., 2020; OECD, 2015; Silva Hernández, 2020). Given the above, the current research aims to contribute to the literature by studying the associations between gender gaps in mathematics and natural science in Colombia and the realization of the right to education in Bogotá D.C., one of the most important cities in South America.

What Does the Right-to-Education Mean?

According to Colombian law, education is both a right of the person and a public service (Asamblea Nacional Constituyente, 1991; Ley 115 de febrero 8, 1994). Education is important because it enables people to develop their knowledge and personality, as well as the skills needed to participate actively in economic, social, political, and cultural activities (Ley 115 de febrero 8, 1994). Even though there is a consensus on the importance of the right to education, defining it is not easy because it encompasses multiple dimensions. In Colombia, the 4A approach of Tomasevski (2004) has been used by academia and the Constitutional Court to define the right to education (Bayona-Rodríguez & Silva, 2020; Bayona Rodríguez et al., 2018; Sentencia T-743-13, 2013; Sentencia C-376/10, 2010).

According to the 4A approach of Tomasevski (2004), the right to education is a construct that encompasses four dimensions: Accessibility, Acceptability, Availability, and Adaptability. The dimension of *accessibility* refers to the ability to access the educational system in equal terms; it also refers to the elimination of any form of discriminatory practices, and the ability to attend compulsory education in person or through modern technologies (Sentencia C-376/10, 2010). In this context, gender gaps may be seen as an indicator of accessibility because they are influenced by traditional stereotypes about the role of boys and girls in society that persist today (Meinck & Brese, 2019). These stereotypes shape teachers' and parents' expectations regarding boys' and girls' achievements and may lead to differences in how they treat boys and girls. Such differences may affect boys' and girls' self-concept, academic achievement, and career choices (Meinck & Brese, 2019).

The dimension of *availability* refers to the government's obligation to provide enough educational institutions, invest in necessary resources, and allow the establishment of educational institutions to ensure that all school-age children can attend compulsory education (Sentencia C-376/10, 2010). The dimension of *acceptability* refers to the quality of education; in other words, it encompasses the quality of instruction and learning processes, teacher training, the results of

educational assessments, the relevance of education for cultural groups, and other criteria identified as important by society (Sentencia T-743-13, 2013; Sentencia C-376/10, 2010; Tomasevski, 2004). Finally, *adaptability* refers to the ability of educational systems to adapt their methods and processes to meet students' needs (Sentencia C-376/10, 2010; Tomasevski, 2004).

Why May Improvements in the Right-to-Education Acceptability, Adaptability, and Availability Indicators Reduce Gender Gaps?

Based on the 4A perspective (Tomasevski, 2004), it is hypothesized that the acceptability of teacher training is key to eliminating all types of discriminatory practices. Teachers who have graduated with a master's or PhD in education should be aware of the negative consequences of gender stereotypes on their actions and the effects these actions have on students' learning. Therefore, they should ensure that these stereotypes are not present in their teaching. Likewise, it is hypothesized that adaptability in educational processes is important for reducing gender gaps because it may encourage teachers to adapt their teaching to meet students' needs and interests, which in turn may enhance students' motivation in their learning. Additionally, improvements in school adaptability may reduce withdrawal rates, which in turn may help students achieve school learning objectives. Finally, it is hypothesized that the availability of educational institutions is important for reducing gender gaps. If all girls and boys have access to schools with the necessary educational resources to provide high-quality education, students are more likely to achieve school learning objectives.

The Current Study

Given the above, the current study aims to answer the following research questions:

1. What are the magnitudes of the gender gaps in mathematics and natural sciences in the public high school system of Bogotá D.C. in 2020?
2. What are the associations between the gender gaps in mathematics and natural sciences and the right-to-education indicators of availability, adaptability, and acceptability in the public high school system of Bogotá D.C. in 2020?
3. What are the associations (both gender-independent and gender-specific) between achievements in mathematics and natural sciences and the aforementioned right-to-education indicators in the public high school system of Bogotá D.C. in 2020?

Data and Method

Data

This study used two sources of information. Firstly, it used the Right to Education Index (hereafter, IDE) database for Bogotá's public education system in 2020. The IDE 2020 aimed to measure the level of realization of students' right to education in the Bogotá public education system (IDE & Universidad de los Andes, 2021). To achieve this, ide 2020 used primary sources of information, which included the Colombian formal education survey, the list of Bogotá's schools, and the enrollment information from the Colombian Ministry of Education (IDE & Universidad de los Andes, 2021).

Secondly, it used the Colombian high school public examination, known as Saber 11, database from 2020. According to Colombian legislation, the objectives of Saber 11 exam include the following: to ascertain the level of development of knowledge and skills of students who are about to finish high school; to provide information to help students develop their life projects; to provide information to higher education institutions about candidates' knowledge and skills; and to monitor the quality of education in Colombia (Decreto 869 de marzo 17, 2010).

Saber 11 assesses five areas: mathematics, reading, natural sciences, social science and citizenship exercise, and English as a foreign language. Furthermore, Saber 11 reports students' performance in these areas and classifies their performance in achievement levels. For f mathematics and natural sciences, Saber 11 classifies students' performance into four levels of achievement, where level 1 is the lowest one and level 4 is the highest (Icfes, 2019c, 2019b).

Population and Sample

This study examines the population of Bogota's public schools and the students from those schools who took Saber 11 exam in 2020. According to the directory of Bogota's schools, the city had 403 public schools. However, it is worth noting that not all these schools offer eleventh grade. Therefore, the analyzed sample encompassed 370 schools. Additionally, this study analyzes a sample of 39,216 students, from the original sample that included 43,629 students. This study excluded only students who did not have the required information to conduct the required statistical analysis.

Measures

Gender gap in mathematics and natural sciences measures

Most studies that analyze gender gaps within countries measure these gaps based on the average differences in results on standardized tests between boys and girls or the differences at different levels of achievement (Meinck & Brese, 2019). Given the above, to achieve a better understanding of the factors associated with gender gaps in mathematics and natural science, this study uses two types of gender gap indicators. Specifically, this study measures gender gaps based on the differences in the average results between boys and girls in the mathematics and natural science test of Saber 11, which are named *Mathematics Gender Gap # 1 and Natural Science Gender Gap # 1*. Similarly, this study measures gender gaps based on the differences at levels 3 and 4 of achievements in the mathematics and natural science test of Saber 11, which are named *Mathematics Gender Gap # 2* and *Natural Science Gender Gap # 2*.

Mathematics and natural science achievement measures

This study measures mathematics and natural science achievements using students' results in these areas in the Saber 11 exam of 2020. It is important to highlight the aims of these tests. Regarding the mathematics test of Saber 11, it aims to evaluate three competencies: interpretation and representation, and argumentation (Icfes, 2019c). Furthermore, the natural science test of Saber 11 aims to assess three competencies: the comprehensive uses of scientific knowledge, the capacity to explain phenomena, and the inquiry capacity (Icfes, 2019b).

Right-to-education measures

This study uses indicators of *availability*, *adaptability*, and *acceptability* dimensions of the right-to-education from the Right to Education Index database for Bogotá's public education system in 2020 (IDEP & Universidad de los Andes, 2021). It is worth noting that all indicators from that database take values between 0% and 100%, where 0% means the absence of the realization of the right-to-education, and 100% means a complete realization of it.

The *availability* indicator was calculated based on variables that measure the required resources to provide high-quality educational services. The variables used to measure this indicator include: the percentage of teachers who hold a bachelor's degree, the student-classroom ratio, the percentage of students who attend school

full-time, the ratio student-computer, the percentage of students who attend a bilingual "*Sede*" or "school physical location" in each educational establishment, and the percentage of "*Sedes*" with access to an internet connection in each educational establishment (IDEP & Universidad de los Andes, 2021).

The *adaptability* indicator was calculated based on variables that measure the extent to which schools adapt their practices to meet students' needs. The variables used to measure this indicator were the schools' rates of students who are overage, dropout, and repeat grades (IDEP & Universidad de los Andes, 2021). Finally, the indicator of *acceptability* was calculated based on variables related to the quality of the education provided by the schools. The variables used to measure this indicator were[3] the percentage of teachers with graduate degrees in education, the percentage of teachers who passed the teacher admission career exam, and the percentage of teachers with temporary appointments (IDEP & Universidad de los Andes, 2021).

Research design and data analysis procedures

This study used a correlational research design (Mertler, 2016) and cross-sectional databases. Therefore, the results of the regression models should be interpreted as correlations or associations, and not as causal effects. To address the research questions, this study conducted descriptive analyses, linear regression analyses, and multilevel regression analyses.

Regarding the descriptive analyses, this study examined gender gaps in mathematics and natural science at the level of schools and localities. Furthermore, this study conducted linear regression models to estimate the associations of gender gaps with the analyzed right-to-education indicators. In these regression models, the dependent variables were the measures of gender gaps in mathematics and natural sciences, and the explanatory variables were the indicators of the right-to-education and the school socioeconomic status (onward NSE, for its acronym in Spanish) (Icfes, 2019a). The NSE is a categorical variable that classifies school socioeconomic status into four categories: NSE 1, NSE 2, NSE 3, and NSE 4, where schools that belong to NSE 1 are more vulnerable, and the schools that belong to NSE 4 are more privileged. The general equation used in these analyses is:

$$Gender\ gap_{it} = \alpha_0 + \sum_{j=1}^{3} \beta_j IDE_{ij} + \alpha_1 NSE_i + u_i \quad (1)$$

[3] On this point, it is worth noting that the indicator of acceptability used in this paper does not include the percentage of students who achieve levels three and four on the mathematics and reading tests of Saber 11 because this variable is associated with the gender gaps analyzed in this paper.

Where $Gender\ gap_{it}$ denotes the gender gaps in school *i* and the test *t*, α_0 is the intercept of the equation, NSE_i denotes the school socioeconomic status, u_i is the error term and $u_i \sim Normal(0, \sigma^2)$. The variable IDE_{ij} denotes the right-to-education indicator *j* (*j*=1,2,3) in school *i*.

To answer the third research question, this study conducted multilevel linear regression models (Snijders & Bosker, 2012). Specifically, this study used multilevel linear regression models where students' scores in mathematics and natural sciences in Saber 11 exam (P_{tji}) were the dependent variables. Similarly, the explanatory variables included in the models were: $Female_{ji}$ ($Female_{ji} = 1$ if the student's gender is female, and $Female_{ji} = 0$ if the student's gender is male); the right-to-education indices (IDE_{ik}), and the interaction terms between Female and the right-to-education indices. Finally, the estimated equations included the following control variables $(Control_{ji})$: student socioeconomic status (Icfes, 2019a), time spent reading for entertainment, time spent surfing the internet, time spent working, the type of remuneration received for their work, school socioeconomic status, and the location of the school (rural vs urban). The general equation estimated was:

$$P_{jit} = \gamma_{00} + \gamma_1 Female_{ji} + \sum_{k=1}^{3} \beta_k IDE_{ik} + \sum_{k=1}^{3} \alpha_k Female_{ji} IDE_{ik} + \sum_{g=1}^{7} \delta_g Control_{ji} + U_{0i} + R_{ji} \quad (2)$$

Where γ_{00} represents the average intercept value that holds across the groups, U_{0i} is a group-specific effect on the intercept or level two random effect, which is assumed to be drawn randomly from a population with a mean of zero and a constant variance, and R_{ji} represents the student error term which is assumed to be randomly drawn from a normal distribution with a mean of zero and a constant variance.

Results

What are the sizes of gender gaps in mathematics and natural sciences?

The results show that boys outperformed girls in mathematics and natural sciences on average in most of the localities of Bogotá D.C. *Mathematics Gender Gap # 1* and *Natural Science Gender Gap # 1*, in favor of boys, range between –0.85 and –6.76 points and –1.09 and –5.73 points, respectively. Additionally, the results show *that Mathematics Gender Gap # 2* and *Natural Science Gender Gap # 2*, in favor of boys, range from 68.68 % to 87.10 % points and 34.82 % to 246.15 %, respectively. It is worth noting that the only locality where *Natural*

Science Gender Gap # 2 was in favor of girls was Sumapaz. Tables 1 and 2 report these gaps by localities.

Table 1

Mathematics' and natural science' gender gap # 1 in Bogotá public schools by localities.

Locality	Girls' average results in mathematics	Boys' average results in mathematics	Mathematics' gender gap # 1	Girls' average results in natural science	Boys' average results in natural science	Natural science' gender gap # 1
Antonio Nariño	54.43	58.22	-3.79	51.19	53.38	-2.19
Barrios Unidos	53.64	56.60	-2.96	50.05	52.27	-2.22
Bosa	50.22	53.83	-3.61	47.50	50.33	-2.83
Chapinero	45.20	50.14	-4.94	43.65	47.04	-3.39
Ciudad Bolívar	49.34	52.69	-3.35	46.43	48.67	-2.24
Engativá	52.38	56.27	-3.89	49.82	52.55	-2.73
Fontibón	51.91	55.60	-3.69	49.02	51.31	-2.29
Kennedy	51.77	55.50	-3.74	48.95	52.09	-3.14
La Candelaria	46.74	50.43	-3.68	45.28	48.17	-2.89
Los Mártires	53.43	60.19	-6.76	50.21	55.94	-5.73
Puente Aranda	54.15	56.78	-2.63	50.94	52.44	-1.50
Rafael Uribe Uribe	50.67	53.83	-3.16	48.20	49.63	-1.43
San Cristóbal	49.55	53.28	-3.73	46.96	49.56	-2.60
Santafé	48.61	52.87	-4.26	46.05	48.63	-2.58
Suba	50.73	53.78	-3.05	48.25	50.35	-2.10
Sumapaz	45.96	46.81	-0.85	44.85	45.94	-1.09
Teusaquillo	51.28	54.34	-3.06	48.76	51.49	-2.73
Tunjuelito	50.09	54.08	-4.00	47.38	50.19	-2.81
Usaquén	49.92	54.06	-4.14	47.44	50.82	-3.39
Usme	50.06	53.55	-3.50	47.18	49.41	-2.23

Table 2
Mathematics' and natural science' gender gap # 2 in Bogotá public schools by localities.

Locality	Percentage of girls at level 3 or 4 in mathematics (a)	Percentage of boys at level 3 or 4 in mathematics (b)	Mathematics' gender gap # 2 ([a / b]*100)	Percentage of girls at level 3 or 4 in natural science (c)	Percentage of boys at level 3 or 4 in natural science (d)	Natural science' gender gap # 2 ([c / d]*100)
Antonio Nariño	68.50	79.67	85.97	32.95	40.65	81.05
Barrios Unidos	64.86	76.05	85.29	25.84	39.22	65.88
Bosa	49.12	64.21	76.49	18.30	28.93	63.25
Chapinero	30.53	44.44	68.68	8.42	11.11	75.79
Ciudad Bolívar	46.10	59.05	78.07	14.83	24.34	60.91
Engativá	58.68	73.83	79.48	27.34	39.49	69.23
Fontibón	56.87	68.86	82.58	25.45	37.13	68.55
Kennedy	57.08	72.62	78.60	22.70	36.77	61.72
La Candelaria	32.56	46.75	69.64	8.14	23.38	34.82
Los Mártires	60.64	84.43	71.83	33.66	51.21	65.73
Puente Aranda	64.79	74.38	87.10	30.36	39.57	76.72
Rafael Uribe Uribe	50.45	64.94	77.68	22.30	27.70	80.51
San Cristóbal	46.52	60.84	76.46	16.67	29.29	56.90
Santa Fé	43.75	61.64	70.97	15	22.83	65.70
Suba	51.40	63.90	80.44	20.18	30.32	66.54
Sumapaz	30.77	43.75	70.33	15.38	6.25	246.15
Teusaquillo	51.54	68.03	75.76	27.69	36.89	75.08
Tunjuelito	51.22	66.01	77.60	16.32	30.18	54.08
Usaquén	47.63	65.02	73.25	18.30	31.35	58.35
Usme	48.37	63.26	76.46	17.00	26.28	64.71

Regarding the mathematics and natural science gender gaps at the school level, the results show that in most public schools in Bogotá, these gaps are in favor of boys. Specifically, *Mathematics Gender Gap # 1* and *Natural Science Gender Gap # 1* are in favor of boys in 345 schools out of 370 and 329 out of 370, respectively. Additionally, *Mathematics Gender Gap # 2* and *Natural Science Gender Gap # 2* are in favor of boys in 334 schools out of 370, and 336 schools out of 370, respectively. Figures 1 and 2 display these gaps.

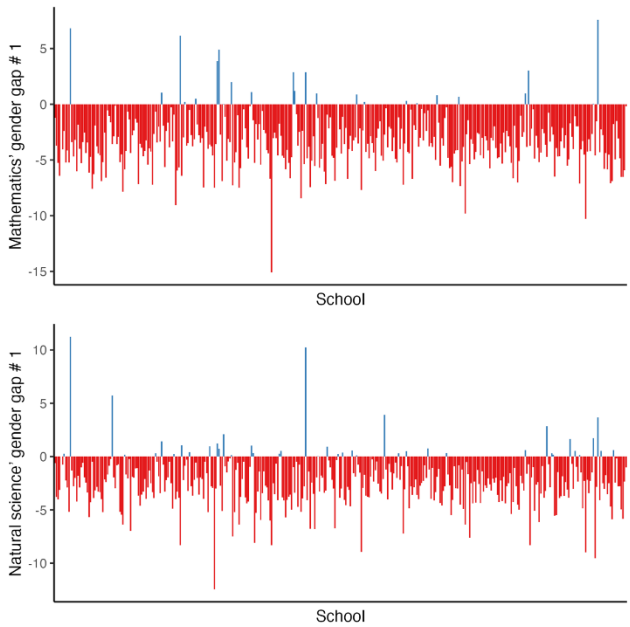

Figure 1. Mathematics' and natural science' gender gap # 1 in Bogotá public schools
Source:

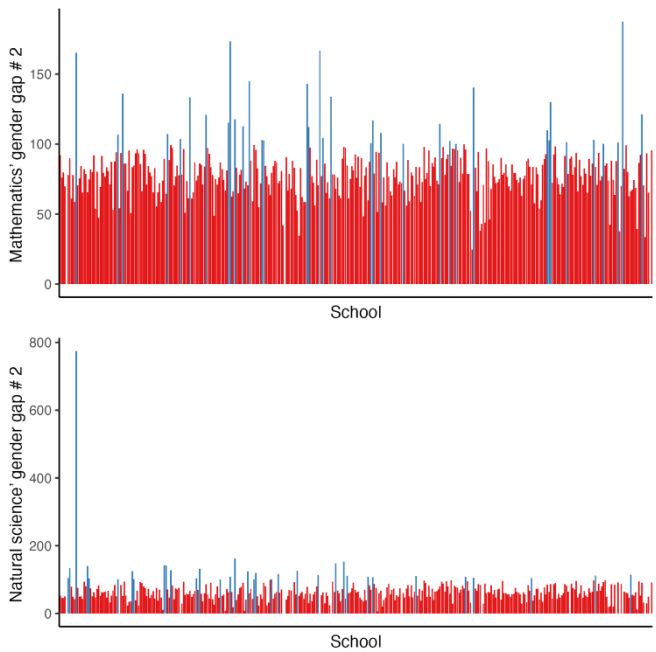

Figure 2. Mathematics' and natural science' gender gap # 2 in Bogotá public schools

What are the associations between the gender gaps and the analyzed righ-to-education indicators?

Table 3 presents the results of the associations between the gender gaps in mathematics and natural sciences and the right-to-education indicators. The results indicate that the gender gaps in mathematics are associated with the *availability* and *acceptability* indicators. Specifically, Model 2 predicts that each 1 percentage point (pp) increase in the availability indicator is associated with a 0.34 pp increase in the *Mathematics Gender Gap # 2* (p-value = 0.015), while keeping all other variables included in the model constant. Additionally, Model 2 predicts that each 1 percentage point (pp) increase in the acceptability indicator is associated with a 0.18 pp increase in *Mathematics Gender Gap # 2* (p-value = 0.059), while keeping all other variables included in the model constant.

Regarding *Natural Science Gender Gaps*, the results show that they are associated with the indicators of *adaptability* and *acceptability*. Specifically, Model 3 predicts that each 1 pp increase in the adaptability indicator is associated with a 0.13-point increase in *Natural Science Gender Gap # 1* (p-value=0.014), while keeping all other variables included in the model constant. Additionally, Model 4 predicts that each 1 pp increase in the acceptability indicator is associated with a 0.52 pp increase in *Natural Science Gender Gap # 2* (p-value = 0.019), while keeping all other variables included in the model constant.

Table 3
Results of regression models for gender gaps in mathematics and natural science.

	Dependent variable:			
	Mathematics gender gap # 1 (1)	**Mathematics gender gap # 2 (2)**	**Natural science gender gap # 1 (3)**	**Natural science gender gap # 2 (4)**
Availability	0.01	0.34**	-0.01	0.05
	(0.02)	(0.14)	(0.02)	(0.33)
Adaptability	0.06	0.10	0.13**	1.79
	(0.06)	(0.47)	(0.05)	(1.09)
Acceptability	0.01	0.18*	0.02*	0.52**
	(0.01)	(0.10)	(0.01)	(0.22)
NSE 3 o 4	-0.58*	0.66	-0.65**	0.30
	(0.32)	(2.71)	(0.31)	(6.31)

Intercept	-10.45**	33.75	-15.45***	-142.14
	(5.29)	(45.05)	(5.18)	(104.60)
Observations	338	338	338	332
R^2	0.02	0.03	0.04	0.03
Adjusted R^2	0.003	0.02	0.03	0.02
Residual Std. Error	2.44 (df = 333)	20.74 (df = 333)	2.38 (df = 333)	47.61 (df = 327)
F statistic	1.29 (df = 4; 333)	2.48** (df = 4; 333)	3.27** (df = 4; 333)	2.39* (df = 4; 327)

*Note. Standard errors (se) are presented in parentheses. Significance codes: * 0,1 ** 0,05 *** 0,01. df: degree of freedom. NSE 2 is the category of reference for NSE.*

What are the associations (both gender-independent and gender-specific) between achievements in mathematics and natural sciences and the right-to-education indicators?

Firstly, this research estimated simple multilevel regression models. Table 4 presents these results. The results indicate that availability, adaptability, and acceptability indicators are associated with mathematics and natural science scores. Specifically, the models predict that each 1 pp increase in the availability, adaptability, and acceptability indicators is associated with a 0.11, 0.28, and 0.08-point increase in mathematics scores, respectively. Additionally, the results show that each 1 pp increase in the availability, adaptability, and acceptability indicators is associated with 0.10, 0.25, and 0.07-point increase in natural science scores.

Table 4
Results of simple multilevel regression models.

	Dependent variable:					
	Mathematics achievements			**Natural science achievements**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Availability	0.11***			0.10***		
	(0.02)			(0.02)		
Adaptability		0.28***			0.25***	

		(0.06)			(0.06)	
Acceptability			0.08***			0.07***
			(0.01)			(0.01)
Random intercept	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	No	No
Observations	43,629	43,629	40,889	43,629	43,629	40,889
$Var(U_{0i})$	9.11	9.65	7.00	7.38	7.71	5.62
$Var(R_{ji})$	90.68	90.67	91.03	75.68	75.67	75.56

*Note. Standard errors (se) are presented in parentheses. Significance codes: * 0,1 ** 0,05 *** 0,01.*

Secondly, this research estimated multiple multilevel regression models. Specifically, this study estimated six models, three for mathematics and three for natural science. Models 1 and 4 in Table 6 are the null models for mathematics and natural science, respectively. Models 2 and 5 present the associations between mathematics and natural science achievements and the variables Female, Availability, Adaptability, and Acceptability, respectively. Finally, models 3 and 6 present the results for the associations between mathematics and natural science achievements and the variables included in models 2 and 5, as well as the interactions between the variable Female and the right-to-education variables.

The results of Models 1 and 4 show that the intraclass coefficients (hereafter, ICC) are equal to 0.10 and 0.097, respectively. Given that around 10% of the variance of achievements in mathematics and natural science is accounted for by school membership, this study concludes that it is appropriate to use multilevel regression models. Additionally, Table 5 shows that the likelihood ratio test is not significant, indicating that the fits of Models 2 and 3 and Models 5 and 6, respectively, are equal. Thus, this study concludes that the inclusion of the interaction terms does not produce a better fit than models that excluded them. Furthermore, the results of Models 3 and 6 in Table 6 show that there is no significant relationship between achievement in mathematics and natural science and the interaction terms between the *Female* and *right-to-education* variables. In other words, the variable *Female* does not moderate the relationships between achievements in mathematics and natural science and the right-to-education indicators.

Table 5
Models fit comparison.

Test	Model	npar	AIC	BIC	logLik	Chi2
Mathematics	2	25	284,338.87	284,553.29	-142,144.43	
	3	28	284,344.66	284,584.81	-142,144.33	0.21
Natural science	5	25	276,039.21	276,253.63	-137,994.60	
	6	28	276,043.61	276,283.76	-137,993.80	1.60

Note: npar: number of model parameters. Loglik: log-likelihood for the model. Chi2: Chi-square statistic of the likelihood ratio test. Significance codes: p<0,05 (*); p<0,01 (**); p<0,001(***).

Given the above, the results of Models 2 and 5 are used to answer the third research question. Models 2 and 5 predict that each 1 pp increase in the availability indicator is associated with a 0.06 and 0.05-point increase in students' achievements in mathematics and natural science, respectively. Furthermore, Models 2 and 5 predict that each 1 pp increase in the indicator of acceptability is associated with a 0.04 and 0.03-point increase in students' achievements in mathematics and natural science, respectively. Finally, Models 2 and 5 predict that girls scored on average 3,54 and 2.63 points less than boys in mathematics and natural science scores.

Table 6
Multiple multilevel regression models for the mathematics and natural science achievements.

	Dependent variable:					
	Mathematics achievement			Natural science achievement		
	(1)	(2)	(3)	(4)	(5)	(6)
Female		-3.54***	-4.85		-2.63***	-5.07
		(0.09)	(3.91)		(0.09)	(3.52)
Availability		0.06***	0.06***		0.05***	0.05***
		(0.01)	(0.02)		(0.01)	(0.01)
Adaptability		-0.005	-0.01		0.01	-0.01
		(0.05)	(0.05)		(0.04)	(0.05)
Acceptability		0.04***	0.04***		0.03***	0.03***
		(0.01)	(0.01)		(0.01)	(0.01)
Female × Availability			-0.003			-0.01

			(0.01)			(0.01)
Female × Adaptability			0.02			0.03
			(0.04)			(0.04)
Female × Acceptability			0.0005			-0.001
			(0.01)			(0.01)
Random intercept	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	Yes	No	Yes	Yes
Observations	43,629	39,216	39,216	43,629	39,216	39,216
$Var(U_{0i})$	10.19	3.43	3.43	8.15	2.35	2.35
$Var(R_{ji})$	90.67	81.23	81.23	75.67	65.81	65.80

*Note. Standard errors (se) are presented in parentheses. Significance codes: * 0,1 ** 0,05 *** 0,01.*

Conclusion

This study has three aims. First, it analyzes the sizes of the gender gaps in mathematics and natural sciences in the high school public sector of Bogotá D.C. in 2020. Second, it estimates the associations between gender gaps in mathematics and natural sciences and right-to-education indicators of availability, adaptability, and acceptability. Third, it estimates the associations (both gender-independent and gender-specific) between achievements in mathematics and natural sciences and right-to-education indicators.

Firstly, the findings of this study show that in almost all Bogotá public schools and localities, gender gaps in mathematics and natural sciences are in favor of boys. Furthermore, the results of the estimated multilevel models show that gender gaps in achievements in mathematics and natural sciences are significantly in favor of boys. Secondly, the results indicate that the gender gaps in mathematics and natural sciences tend to be in favor of girls in schools with better characteristics of availability, adaptability, and acceptability. Thirdly, the simple multilevel models show that increases in availability, adaptability, and acceptability indicators are associated with increases in achievement in mathematics and natural sciences. Furthermore, the results of the multiple multilevel regression models show that achievements in mathematics and natural sciences are associated with the availability and acceptability indicators.

These results provide useful information to Bogotá educational stakeholders because they describe in detail the size of gender gaps in mathematics and natural sciences in the public education system. This descriptive information helps to understand the magnitude of this phenomenon in Bogotá. Additionally, this is the first study that examines the associations between gender gaps in mathematics and natural

science and right-to-education indicators of availability, adaptability, and acceptability. Therefore, this study's results are useful to understand the possible implications of increases in these dimensions of the right-to-education on students' achievements and gender gaps in mathematics and natural sciences.

The results of this study should be interpreted while taking into consideration its limitations. Firstly, given its correlational design and the cross-sectional databases used in its analyses, this study did not examine causal or temporal relationships between students' achievements and gender gaps in mathematics and natural science and the right-to-education indicators of availability, adaptability, and acceptability. Secondly, this study did not analyze indicators that account for discriminatory practices against girls, which may affect students' achievements and gender gaps in mathematics and natural sciences.

Given the above, future studies should address these limitations. Firstly, there is a need to examine the longitudinal relationships between students' achievements and gender gaps in mathematics and natural sciences and the right-to-education indicators. Furthermore, it is important that future studies examine these relationships in both the public and private education systems of Bogotá and other Colombian cities to examine tendencies in these relationships across Colombia.

Additionally, future studies should examine the causal relationships between gender gaps and traditional stereotypes regarding the role models for boys and girls that are present today in Colombian culture. To do this, future studies should examine the main stereotypes in the role models followed by boys and girls in Colombian society. Based on this, they should implement actions to change the perspective of girls, boys, youth, parents, and teachers regarding these stereotypes. Furthermore, future studies should assess the impact of these actions on students' achievements and gender gaps in mathematics and natural sciences.

Finally, future studies should research the main discriminatory practices against girls in Colombia. Based on this identification process, educational stakeholders may implement strategies to change these practices and then assess the impact of these changes on students' achievements and gender gaps in mathematics and natural sciences.

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