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The influence of Brazilian school infrastructure and teacher training on student performance in the area of Natural Sciences

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ABSTRACT. As in other countries, Brazil has used standardized tests as a tool to measure the quality of education. The Ministry of Education, incorporated large-scale assessments into its educational policy in the early 1990s through the System for Basic Education Assessment. In addition to the exam used to assess elementary school, students are also assessed through the National High School Exam, created in 1998 to assess school performance at the end of Basic Education. This study investigates student performance of Brazilian state public schools in the 2017 National High School Exam [ENEM] area of Natural Sciences. We compared student performance between different types of public schools localized in urban and rural areas. In addition, the factors that may cause these differences were assessed. The influence of school infrastructure, proportion of teachers with training in the area of Natural Sciences, and teacher qualification was evaluated upon student performance. Student performance varied by the type of school and between both rural and urban schools with the higher scores founded in civic-military schools and urban areas. Among the factors evaluated, school infrastructure was the most important factor in student performance, followed by the proportion of teachers with a background in Natural Sciences, and finally, teacher qualification. The heterogeneity of performance between school type and location shows how much we still need to improve resource management, school infrastructure, teacher training and qualification.

Keywords: student performance; teacher training; school infrastructure; quality of education.

A influência da infraestrutura escolar e formação docente no desempenho dos estudantes na área de Ciências da Natureza

RESUMO. Assim como em outros países, o Brasil tem utilizado testes padronizados como ferramenta para medir a qualidade da educação. O Ministério da Educação, incorporou as avaliações em larga escala em sua política educacional no início dos anos 1990 por meio do Sistema de Avaliação da Educação Básica (Saeb). Além do exame utilizado para avaliar o ensino fundamental, os estudantes também são avaliados por meio do Exame Nacional de Ensino Médio (ENEM), criado em 1998 para avaliar o desempenho escolar ao final da educação básica. Este estudo investiga o desempenho dos estudantes de escolas públicas estaduais brasileiras na área de Ciências da Natureza, no ENEM de 2017. Foi comparado o desempenho dos estudantes entre diferentes tipos de escolas públicas e entre escolas localizadas em áreas urbanas e rurais. Além disso, os fatores que podem causar essas diferenças foram avaliados. A influência da infraestrutura escolar, proporção de professores com formação na área de Ciências da Natureza e qualificação docente no desempenho dos estudantes foi avaliada. O desempenho dos estudantes variou com o tipo de escola frequentada e entre escolas rurais e urbanas, com os melhores desempenhos sendo apresentado por escolas cívico-militares e localizadas em áreas urbanas. Entre os fatores avaliados, a infraestrutura escolar foi o fator mais importante no desempenho dos alunos, seguido pela proporção de professores atuando nas suas respectivas áreas de formação e a qualificação destes professores. A heterogeneidade do desempenho entre tipo de escola e localização mostra o quanto ainda precisamos melhorar a gestão de recursos, a infraestrutura escolar, além da formação e qualificação de professores.

Palavras-chave: desempenho dos estudantes; formação docente; infraestrutura escolar; qualidade da educação.

La influencia de la infraestructura escolar y formación docente en el desempeño de los estudiantes en el area de las Ciencias de la Naturaleza

RESUMEN. Así como en otros países, Brasil utiliza pruebas padronizadas como herramienta para medir la calidad de la educación. El Ministerio de Educación, ha incorporado las evaluaciones en larga escala en su política educacional a principios de los años 1990 por medio del Sistema de Evaluación de la Educación Básica. Además del examen utilizado para evaluar la enseñanza fundamental, los estudiantes también son evaluados por medio del Examen Nacional de la Enseñanza Media (ENEM), creado en 1998 para evaluar el desempeño escolar al final de la Educación Básica. El presente estudio investiga el desempeño de los estudiantes de escuelas públicas estatales brasileñas en el área de Ciencias de la Naturaleza, en el ENEM del año 2017. Fue comparado el desempeño de los estudiantes entre distintos tipos de escuelas públicas y entre escuelas ubicadas en zonas urbanas y rurales. Además, los factores que pueden causar esas diferencias fueron evaluados. La influencia de la infraestructura escolar, proporción de profesores con formación en el área de Ciencias de la Naturaleza y calificación docente en el desempeño de los estudiantes fue evaluado. El desempeño de los estudiantes ha variado con el tipo de escuela frecuentada y entre escuelas rurales y urbanas siendo los mejores desempeños presentados en escuelas cívico-militar localizadas en zonas urbanas. Entre los factores evaluados, la infraestructura escolar fue el factor más importante en el desempeño de los alumnos, seguido por la proporción de los profesores actuando en sus respectivas áreas de formación y la calificación de estos profesores. La heterogeneidad del desempeño entre el tipo de escuela y la localización ha enseñado cuanto aún necesitamos mejorar la gestión de recursos, infraestructura escolar, además de la formación y calificación de los profesores.

Palabras clave: desempeño estudiantil; formación docente; infraestructura escolar; calidad de la educación.

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Introduction

As access to education has expanded in developing countries, global education policies have focused attention on the quality of education provided (Carnoy et al., 2015). Standardized tests have been used as a tool to measure the quality of education and studies have shown a strong relationship between student performance and economic development (Hanushek & Woessman, 2007; Pritchett & Viarengo, 2009).

In Brazil, the Ministry of Education (MEC), incorporated large-scale assessments into its educational policy in the early 1990s through the System for Basic Education Assessment (Saeb). In addition to the Saeb, students are also assessed through the National High School Exam (Exame Nacional do Ensino Médio - ENEM), created in 1998 to assess school performance at the end of basic education. Unlike the Saeb, the ENEM is not mandatory, but it has a strong adherence, since it is used as college selection criterion by most Brazilian universities. Besides the national test, Brazil participates in the Program for International Student Assessment - PISA, applied by the Organization for Economic Cooperation and Development - OECD. The test is applied to 15-year-olds, the age at which they are reaching the end of compulsory education in most OECD countries. The test assesses the skills developed by students in the teaching-learning process in the areas of reading, mathematics, and science.

Despite the advances achieved in basic education in Brazil, assessments such as PISA, which compare the literacy of students from several countries, have shown that the average Brazilian student remains below the average of other OECD participating countries. Data from the 2018 edition of PISA puts Brazil in the lower ranking of assessed countries, with averages of 384 points in math, 413 in reading, and 404 in science, below the OECD averages of 489, 487, and 489 points respectively. The study also points out that Brazil's average in science (404 points) is equivalent to three school years less than the countries that are in the OECD average (489 points) (Brasil, 2019b). These reports however, have focused on disclosing student performance without a contextualization of the conditions of education supply, focusing only on the cognitive aspects of students, when it should illustrate the efficiency of public policies adopted and their contribution to the quality of education (Bautheney, 2019).

PISA has been used as a regulatory tool to conduct public policies in countries, since the policies adopted for education in participating countries are linked to the improvement of test scores. In the case of Brazil, PISA is adopted as a reference model for both statistics and quality of education, present in goal 7.11 of the

National Education Plan (Plano Nacional de Educação - PNE) (Hypolito & Jorje, 2020). It is an international trend of standardization of performance dissociated from the foundations of educational policy as a responsibility of the State.

Some educational reforms have recently been implemented in Brazilian education with the justification of achieving quality education. Law No. 13,415 of February 16, 2017 changes the Law of Directives and Bases of National Education (*Lei de Diretrizes e Bases da Educação Nacional* - LDB) in several aspects, such as the minimum workload for elementary and high schools, which went from 800 hours per year to 1,000 hours, with a five-year transition period starting in March 2017. Gradually, schools will have to offer 1,400 hours per year, becoming full-time schools. The composition of the curriculum should contemplate the National Common Curricular Base (*Base Nacional Comum Curricular* - BNCC), with a maximum of 1,800 hours for its completion, and the other part for training content, with five curricular arrangements, including technical and vocational training (Hernandes, 2020). In 2019, with the change of federal government, Civic-Military schools gained prominence in public policies. The government directed technical and financial resources to the expansion of this school modality (Brasil, 2019a).

The quality of education, however, involves many aspects and should be unfolded in the quality of each of the school structures and the results of the school processes (Soares, 2009). Thus, several factors are pointed out as essential for quality education, such as improving school infrastructure, hiring qualified teachers, community participation in school life (Masino & Nino-Zarazua, 2016), parents' schooling, family income, as well as school location, all of which can also impact student performance (Lopes et al., 2020; Nogueira et al., 2015).

Given the above, a study on the influence of the infrastructural conditions of schools and teaching professionalization on the performance of high school students based on data from ENEM and the School Census is relevant, as they are national data that represent the reality of Brazilian schools. The present study aims to analyze the performance of students from Brazilian state public schools in the 2017 ENEM in Nature Sciences, by comparing the performance of students from different types of schools located in rural and urban areas in all of Brazil. In addition, this study will verify the influence of school infrastructure, proportion of teachers working in their respective areas of training and teaching qualifications on student performance.

Materials and methods

Dataset

For this study, we used microdata from the National High School Exam (ENEM) and the School Census of Basic Education (School Census), both conducted in 2017. The 2017 edition is justified because it presents the School Census database with fewer missing data. The data were collected by the National Institute of Educational Studies and Research Anísio Teixeira (INEP) and are available at http://portal.inep.gov.br/web/guest/microdados.

To compose the sample of this study, the Natural Science scores of students from state public schools in Brazil were selected from the ENEM database, considering as inclusion criteria, the student being a high school graduate, having taken the tests of the four knowledge areas and having attended all high school in a public school environment. After selecting the variables and applying the filters, the average performance per school was calculated and used to represent the students' performance.

Based on the information present in the School Census, the schools were grouped into six types (Table 1): Specialized for Youth and Adults [EJA], Regular, Mediation, Vocational, Indigenous, and Civic-Military. Civic-military schools are not categorized in the School Census database, so the information was sought from the MEC through the Electronic System of Citizen Information Service (e-SIC).

Only schools in which the shared management system was implemented by 2014 were classified as Civic-Military. This cutoff was necessary to ensure the minimum time of three years for students to complete their high school education in these schools, since the data collected are from 2017, and one of the objectives of this study is to verify student performance according to the type of institution where the student completed all of his high school education. The schools that implemented Civic-Military management after the year 2014 were classified according to the characteristic that best defined it, in this case, they were classified as regular.

Table 1. Characterization of schools regarding the administrative and pedagogical didactic system of Brazilian state schools present in the 2017 School Census (INEP, 2018).

School type	Description
Regular	The variable is composed of regular schools, which follow common education, with established levels of teaching and age groups, and regular schools that have classes for Youth and Adults (EJA).
Civic-Military	The variable is composed of regular schools that have shared management between civilians and military that are under the responsibility of the Secretary of Security and the Secretary of Education.
EJA	The variable is comprised of specific schools for youth and adults (EJA), i.e., for people who have not attended elementary and/or high school at an appropriate age.
Mediation	The variable is comprised of EJA schools that do semi-attendance didactic pedagogical mediation or at a distance, mediated by technology.
Vocational	The variable is comprised of regular schools and EJA schools that offer vocational courses integrated or concomitant to high school.
Indigenous	The variable is composed of regular schools and EJA schools that are specific for indigenous people.

For the characterization of school infrastructure, 40 variables present in the School Census were used. Only dichotomous variables were used, that is, variables that indicate absence (0) or presence of the item (1). Some variables even being dichotomous were not used because the desired information was already present in the selected item. For example, the variable indicating whether or not the school has a public water supply was included, which is the desired information, while the information on the artesian well supply was not included, since it is not the purpose of this research to know other sources of water supply. Items such as VHS players, overhead projectors, and satellite dishes were not included because they have been rendered obsolete over time. In addition, items that characterize only the infrastructure of schools for early childhood education, such as nurseries, playgrounds, and children's bathrooms, were not included, because the research only involves secondary school students.

The infrastructure of schools was quantified using Item Response Theory (IRT) (Andrade et al., 2000). For this study, the two-parameter logistic model was used, parameter 'a' of discrimination and parameter 'b' of difficulty. The parameter 'a' will discriminate how well the item distinguishes the infrastructure of schools, the higher its value the better the item distinguishes the levels of infrastructure of schools. The parameter 'b' difficulty, can be interpreted as the difficulty that the school has in presenting a certain item of infrastructure. In the calibration phase of the items, the variables filtered water, food, public sewage, outside bathrooms, covered patios and fax machines were removed from the model because their discrimination parameters were too low (less than 0.06 distance of 0), leaving only 33 variables. A new analysis was performed to estimate the parameters of the items (Table 2). Based on these parameters, IRT estimates an Infrastructure Score, that is, it generates a score for each school. For this analysis, the statistical package ltm was used (Rizopoulos, 2007).

After estimating the infrastructure scores for each school, they were transformed into a scale with mean of 50 and standard deviation of 10 in order to facilitate interpretation and comparison, following the methodology used by Soares Neto et al. (2013). Besides being used as a grade and infrastructure for each school, the scores were used as a grade of infrastructure for each school and also in the development of an infrastructure scale based on anchor items (Soares Neto et al., 2013). Thus, schools were categorized into three levels of infrastructure: Essential, Basic, and Adequate.

At the Essential level, schools are characterized only by the anchor items: public electricity and kitchens. At the Basic level, in addition to the previous items, schools are characterized by the added anchor items: public water, regular garbage collection, faculty lounge, televisions, computers, and internet. At the Adequate level, schools are characterized by the items from the previous two levels and by the added anchor items: athletic courts, photography equipment, broadband internet access, and a special needs bathroom. Science labs, special needs room, special needs facilities, showers, auditoriums and green areas are not considered anchor items and are present in less than 65% of the schools.

The Teachers dataset was used to select the variables referring to the area of expertise, area of occupation, and highest level of education completed for the teachers. Only the teachers who currently administer Natural Sciences subjects (Chemistry, Physics and Biology) were selected. When a teacher worked in the same area of their study, they were classified as a teacher who works in the same area. There was no distinction made between Bachelor's and Teaching certificate courses to evaluate the relationship between area of expertise and area of activity. For each school, the proportion of teachers working in the same area of their study was calculated.

Table 2. Estimates of the parameters of difficulty and discrimination for the items of the infrastructure scale.

Description	Parameter	
	a. Discrimination	b. Difficulty
Public Water	-0.91332957	-1.24051574
Public Electricity	2.18158074	-1.74520419
Regular Garbage Collection	1.27058392	-0.87081601
Principal's Offices	0.30200685	-0.8513457
Faculty Lounge	1.72041572	-0.55751681
Computer Lab	0.44599301	-0.3729769
Science Lab	0.15243795	1.01785593
Special Needs	-1.11592148	1.42472785
Athletic Courts	0.11902132	-0.02976832
Kitchen	0.25236662	-1.29022072
Library	-0.84344276	0.11704261
Inside Bathrooms	-0.9004142	-0.98585876
Special Needs Bathroom	-0.24231029	0.40745995
Special Needs Facilities	-0.23265909	0.89870138
Secretary's Offices	1.45353004	-0.47511167
Showers	-0.61749475	1.07086487
Cafeteria	-0.51311184	0.74348107
Pantry	-0.31741031	0.32011183
Storage Room	-1.00570263	0.55550159
Auditorium	-0.08167596	1.65865291
Green Area	0.01913618	1.1249568
Laundry Area	-0.87569407	3.03301921
Television	0.65006937	-0.77123837
DVD Player	-0.99801705	-0.55719301
Copier	-1.40915344	0.42611638
Printer	-1.19438193	-0.86406264
Laser Printer	-1.34281554	0.22490686
Stereo	-0.10946005	-0.3659608
Multimedia Equipment	0.94835221	-0.39543512
Photography Equipment	-0.11239541	-0.03060369
Computers	1.81174739	-0.84239052
Internet	1.73770059	-0.55066829
Broadband Internet	-0.23955155	-0.22651197

For the teachers working in their area of expertise, the qualification at post-graduate level (Specialization, Master's or Doctoral degrees) was verified, for this, only the highest level of qualification was considered and the proportion of Specialist, Master's and Doctorate teachers per school was calculated. Only schools with at least one teacher working in their study area were included in the sample. This decision was made to keep the number of schools the same in all analyses.

All filtered databases were joined with the help of the function 'semi_join' from the statistical package dplyr (Wickham et al., 2020). The individual code of each school was used as a common variable in all databases, with the ENEM data as the reference to verify the correspondence of the codes. Schools with missing data were excluded. The entire database used in this work is available in https://github.com/Gilvane-Gomes/Banco-de-dados-ENEM (Gomes, 2021).

Data analysis

Two-way Analysis of Variance (ANOVA) was used to assess whether student performance in Natural Science differs between school type and location. When the result of the Anova was significant (p-value<0.05), the Tukey post-hoc test was used to assess which means showed significant differences (Sokal & Rohlf, 1995). The normality of the residuals was tested using the Anderson-Darling test (Razali & Wah, 2011) and the homogeneity of variances was tested using Bartlett's test (Sokal & Rohlf, 1995). Since the residuals did not show a normal distribution and the variances were not homogeneous, a Kruskal-Wallis test (non-parametric) was used. However, since there was no difference between the two tests, we decided to present the ANOVA results.

We performed a multiple linear regression to assess whether the proportion of teachers working in their respective study areas, number of teachers with specializations, master's or doctoral degrees, and school infrastructure represented by the scores affected student performance (average of schools) (Zar, 2019). The importance of each variable for the multiple linear regression model was assessed using the function

'lm.beta', from the 'QuantPsyc' package (Fletcher, 2012). This function standardizes the coefficients and creates a rank of importance for each variable.

The organization of the database for this research and the statistical analyses were performed with the help of the R program (R Core Team, 2021) and a significance level of 5% was adopted (p-value <0.05) for all hypothesis tests.

Results

School characterization

We analyzed a total of 17,624 public schools in Brazil. Of these, 91.1% are located in urban areas including all of the Civic-Military, Mediation and EJA. While the other categories are found in both urban and rural areas (Table 3).

Table 3. Distribution of public schools by school type and location.

School Type	Location		Total Schools
	Rural	Urban	
Civic-Military	0	84	84
EJA	0	131	131
Indigenous	64	3	67
Mediation	0	154	154
Vocational	139	2447	2586
Regular	1371	13231	14602
Total	1574	16050	17624

Students' scores in Natural Sciences showed significant differences between School Type and Location (ANOVA: F=258 and p<0.001, Table 4 and Figure 1). Civic-Military schools outperformed the other schools with 540.79 points, followed by Vocational schools with 495.82 points and Regular schools with 483.04 points. Mediation (477.43) and EJA (472.36) schools, on the other hand, showed no significant difference in performance. Indigenous schools had the lowest performance (459.53) (Table 4 and Figure 1). Student performance also differed by school location. Students from urban schools outperformed students from rural schools (Table 4), scoring an average of 485.21 points and 475.82 points, respectively.

Table 4. Mean±Standard Deviation (SD) of Natural Science scores of state public school students by school type and location.

Variables	N	Mean±SD	F	df	p-value
		School Type			
Civic-Military	84	540.79±33.4^{a}	258.36	5;17617	<0.001
Vocational	2586	495.82±27.1^{b}			
Regular	14602	483.04±21.7^{c}			
Mediation	154	477.43±41.4^{d}			
EJA	131	472.36±45.5^{d}			
Indigenous	67	459.53±36.3^{e}			
		Location			
Urban	16050	485.21±23.3^{a}	81.28	1;17617	<0.001
Rural	1574	475.82±29.8^{b}			

Different letters indicate that there was significant difference between means (Tukey post-hoc tests); F = statistic from Anova test; df= Degrees of Liberty.

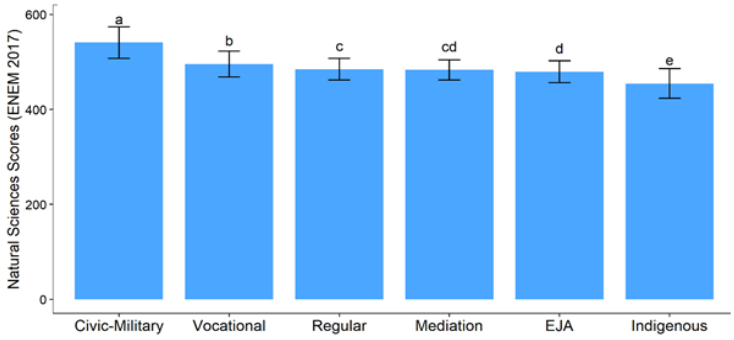

Figure 1. Mean±Standard Deviation of Natural Science scores of state public school students according to the

School type

The schools were classified into three levels of school infrastructure: Essential, Basic, and Adequate, where 0.44% of the schools have essential infrastructure, 12.95% have basic infrastructure, and 86.58% have adequate infrastructure. No school has reached the advanced infrastructure level.

The schools with the highest frequency at the Adequate level were the Civic-Military (95.24%), followed by Vocational (93.23%), and Regular (85.84%) schools. At the Basic level were the Indigenous schools (65.25%), EJA (26.71%), Mediation (20.77%), and Regular (13.66%) schools. At the Essential level were the Indigenous (10.44 %), followed by the EJA (1.52%), and Regular (0.49%) schools. No Civic-Military schools have infrastructure at the Essential level (Figure 2).

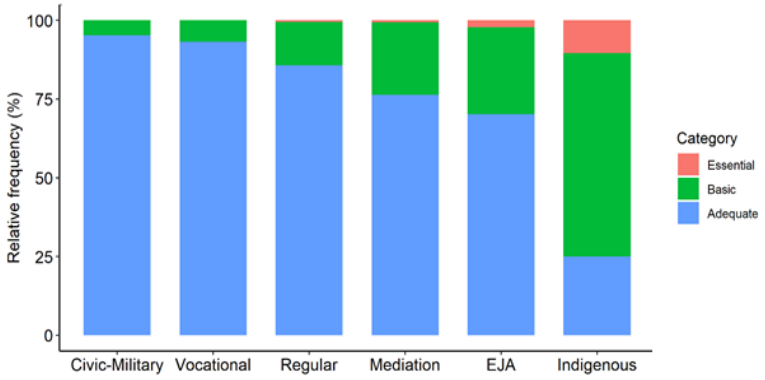

Figure 2. Frequency of schools according to the level of infrastructure in each School Type based on data from the 2017 School Census (INEP, 2018).

In relation to location, in rural areas, 4.13% of schools present an Essential level of infrastructure, 36.47% a Basic level, and 59.40% an Adequate level. As for urban schools, 0.11% have an Essential level, 10.64% have a Basic level, and 89.25% have an Adequate level (Figure 3).

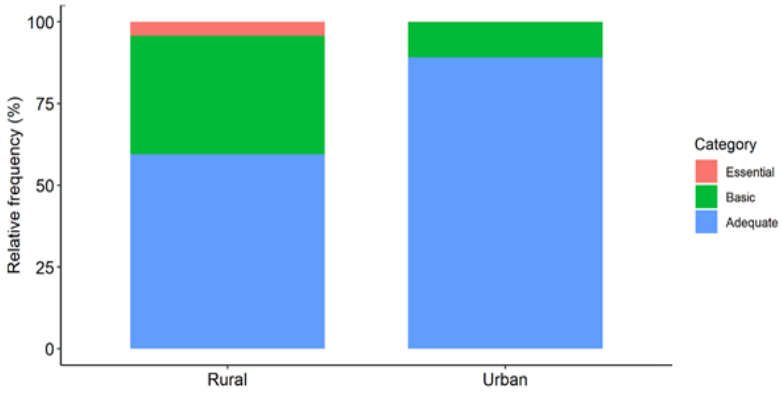

Figure 3. Proportion of schools according to the level of infrastructure in rural and urban areas based on data from the 2017 School Census (INEP, 2018).

As for the area of activity, Civic-military schools have the highest percentage of teachers working in their areas of expertise (70.16%), followed by Mediation (63.14%) and Vocational (60.84%) schools (Table 5). Regular schools (56.83%) and Indigenous schools (46.55%) had the lowest percentages of teachers working in their areas of expertise. While schools located in urban areas had a slightly higher percentage of teachers working in their area of expertise (57.61%) than schools located in rural areas (56.73%) (Table 5).

As for the qualification of the teachers who work in their area of expertise, it can be observed that a Specialization is the most common post-graduate degree, even so, less than half of the teachers are specialists (36%). Only 6% of the teachers have a Master's degree, while less than 1% have a Doctorate. Among the types of schools with the highest percentage of higher degrees are Civic-Military and Vocational schools, with 9% and 6.5% of Master's and 1.7% and 1.3% of Doctors, respectively. As for location, urban and rural schools have similar percentages of Specialists, Masters, and Doctors (Table 5).

Table 5. Proportion of teachers with specialization, master's, and doctorate degrees according to School Type and Location.

School Type	Teachers who work in their area of expertise (%)	Highest Level of Education		
		Specialization (%)	Master's (%)	Doctorate (%)
Civic-Military	70.16	28.52	9	1.7
Mediation	63.14	41.94	6.2	0.5
Vocational	60.84	42.39	6.5	1.3
EJA	60.77	42.03	7.4	0.7
Regular	56.83	35.21	5.7	0.8
Indigenous	46.55	29.55	2.3	0.0
Location				
Urban	57.61	36.25	5.8	0.9
Rural	56.73	37	5.5	0.8

The multiple linear regression revealed a positive and significant correlation between student performance, school infrastructure, the proportion of teachers working in their respective areas of expertise, and teaching qualifications (Specialization, Master's, and Doctorate) ($R^2 = 0.075$; $p < 0.001$, Table 6). After standardizing the coefficients, it was observed that the variables in the regression model most strongly associated with student performance are, in descending order: infrastructure (0.23), proportion of teachers working in their area of expertise (0.080), Master's degree (0.049), Doctorate (0.047) and Specialization (0.041).

Table 6. Results of the multiple linear regression assessing the impact of school infrastructure (Scores), the presence of teachers in their respective areas of expertise, and teaching qualifications on student performance in the 2017 ENEM Natural Sciences exam.

Variables	Estimate	Standardized	SE	t	p-value
Intercept	455.60		0.928	490.77	<0.001
Infrastructure	0.58	0.23	0.018	32.21	<0.001
PE	2.04	0.08	0.175	5.67	<0.001
Specialization	1.00	0.041	0.176	6.74	<0.001
Master's	1.18	0.049	0.176	6.53	<0.001
Doctorate	1.14	0.047	0.174	11.62	<0.001

PE= teachers in their respective areas of expertise; SE= Standard Error; t= test t.

Discussion

Among the state public schools with the best performance in Natural Science, Civic-Military and Vocational schools stand out. Civic-Military schools have their own regulations in each Brazilian state; however, most of them reserve places for children and dependents of military police officers and firefighters. Additionally, they conduct a selection process for civilian students through tests or lotteries (Cruz, 2017; Mendonça, 2019; Ximenes et al., 2019). This school model has been justified by its ability to control violence and improve school performance rates through safety and discipline, which has led to parental preference and increased demand (Pinheiro et al., 2019).

Given the increased demand, many regular state schools have adopted military management through partnerships between the Secretary of Education and the Secretary of Public Safety (Tiellet, 2019). As a result, these schools receive financial incentives from both the State Department of Education and the State Department of Public Safety (Cruz, 2017). These incentives are evident, as most schools have infrastructure at an adequate level. Additionally, there is a higher proportion of teachers teaching subjects related to their area of expertise. This data supports Santos (2010), who states that schools that adopt shared management experience improvements in infrastructure and teaching staff.

In 2019, the country had a total of 214 Civic-Military schools, 203 public and 11 private, present in 23 states and the Federal District (Brasil, 2019c). In 2020, 53 more schools joined the Civic-Military model, under the National Program of Civic-Military Schools (Pecim) (Brasil, 2019a). Currently, with the change in federal government, Civic-Military schools are no longer incentivized by the federal government, and each state is required to reintegrate state schools into regular networks (Brasil, 2023).

As for Vocational schools, despite having a lower average score than Civic-Military schools, they have a similar level of infrastructure. The improved infrastructure of these schools in relation to the others can be explained by the strong incentive of public policies, as this education modality is directly linked to the labor market (Vieira & Souza Junior, 2016).

The Regular modality is the most frequent type of public schools in Brazil, representing 82.8% of state schools. The target audience of these schools are students who are theoretically at the appropriate age/grade, that is, students between 15 and 17 years old, but with the greatest difference in socioeconomic profiles. The heterogeneity of the Brazilian territory (Araujo & Flores, 2017), as well as the investments made by their respective states, reflects the structural characteristics of schools that in turn impact student performance.

EJA and Mediation schools have a similar target audience and, unlike Regular schools, they serve youth and adults who did not attend high school at the appropriate age/grade. The main difference between the two modalities is that in Mediation schools the classes are face-to-face, but mediated by technology, i.e., students gather in the same place and watch the classes live through multimedia technology or satellite transmission, with audio and video interaction among all participants, with only one teacher-tutor present (Melo Neto et al., 2011). In Brazil, the state of Amazonas is the main reference in technology-mediated education. It was implemented in 2007, to serve elementary and high school students who live in regions with difficult access, considering that some municipalities have access only by river and lack teachers interested in working in these locations (Santos & Cruz, 2020).

The lowest average score in Natural Sciences was from students of Indigenous schools, which needs to be analyzed considering the specificities of indigenous education, considering that, despite following a national basis, these schools have their own differentiated organization where specific indigenous curricular content is prioritized, based on indigenous knowledge and culture (Brasil, 1988, 1996). However, even with the legal provisions, Indigenous school education is affected, mainly by the lack of indigenous teachers, since non-indigenous teachers, in most cases, do not know the indigenous culture and have difficulty with the language (Félix et al., 2017). Given these specificities, the ENEM may not be the appropriate tool for the evaluation of Indigenous school education. On the other hand, the quality and equity, of education, needs to be part of all stages and modalities (Brasil, 1988, 2012, 2014).

The improved performance of students from urban schools, when compared to students from rural areas, is also observed internationally. Studies conducted by PISA show that students attending urban schools perform better than students attending schools in rural areas. This difference is attributed, in part, to the better socioeconomic conditions of students in urban schools, school infrastructure, and greater autonomy in resource allocation with more qualified teachers than in rural schools (Organização para a Cooperação e Desenvolvimento Econômico [OECD], 2013).

Although most state schools were categorized as Adequate, this information deserves caution, as the mere presence of a certain item in the school does not guarantee its good condition. For example, having a science lab is important, but it needs to be well-maintained and equipped with the necessary materials for classes to be truly useful in facilitating learning. Nevertheless, students from schools with higher infrastructure scores performed better. These results are consistent with previous studies that have shown an association between school facilities (library, laboratory, water, and sanitation) and student performance (Kamaruddin et al., 2009; Ramli et al., 2018).

Teachers are another crucial factor in improving the quality of education (Organização para a Cooperação e Desenvolvimento Econômico [OECD], 2020). For teachers to positively impact student performance, it is expected that they have appropriate academic background and training in the subject they are teaching (De Biasi, 2009; Carmo et al., 2015). However, in state schools in Brazil, on average, 57% of Natural Science subjects are taught by teachers with degrees in other areas. The most affected schools are Indigenous, EJA (Youth and Adult Education), and Regular schools. Classes taught by teachers from unrelated fields can lead to a lack of student interest in the subject and school dropout (Costa et al., 2020).

In addition to the teachers who work in their respective areas of expertise, less than 50% have post-graduate degrees. One of the reasons given by Brzezinski (2014) for the low qualification is the lack of substitute teachers to cover classes while these working teachers pursue further education, which leads to teachers dropping out. Alternatively, if they choose to continue their studies, they are forced to pay for the substitute themselves.

Another problem in Brazil is that the teaching profession is not valued according to its relevance to society. In its 2017 report, the World Bank proposed increasing the number of students per teacher, reducing the number of teachers hired, and limiting the hiring of permanent teachers, claiming that it is more difficult to fire them. According to the report, these adjustments would save 1% of the GDP spent on education (World Bank, 2017). In Latin American countries, including Brazil, due to the devaluation of the teaching profession, most young people

show no interest in the profession, unlike what occurs in countries with high performance in international exams such as Finland, South Korea, Hong Kong, and Japan, where choosing the teaching profession is even valued higher than choosing an engineering profession (Elacqua et al., 2018).

The proportion of teachers working in their field of training, teacher qualifications and school infrastructure have a significant effect on student performance but explain only 7.5% of the variance in Natural Science results. These results are consistent with previous studies showing the impact of well-structured schools and qualified teachers on student performance (Chiu & Khoo, 2005; Ramli et al., 2018). However, considering that the coefficient of determination ranges from 0 to 1, a coefficient of 0.075 (7.5%) explains only a small part of the variation in grades. Among the variables analyzed, it is observed that the availability of adequate infrastructure is the factor with the greatest influence on students' grades, while the variables related to teacher specialization do not exert the expected intervention. This raises the question: to what extent did ENEM assess the curricular content of Brazilian public schools? In addition, the quality of teacher training is questionable because, even if the teacher works in their area of training, most of the time the undergraduate curriculum is not compatible with the curriculum required in Basic Education (Gatti, 2016). Such a pedagogical anomaly can have a direct impact on the teaching-learning relationship, since such incompatible curricula do not contribute to the training of students, considering that teachers may take longer to acquire such knowledge necessary for teaching practice in basic education.

The variables related to teacher training and qualification, although significant for student performance, showed less influence on the overall scores, especially doctoral degrees. This demonstrates that student performance is minimally affected by the presence of teachers with higher levels of qualification. That raises some questions. Are the postgraduate courses (Specialization, Master's, and Doctorate) undertaken by these professors aligned with the curriculum content and teaching? Are they consistent with the teacher's area of expertise and training? Furthermore, another factor that may contribute to reducing the effect of teacher qualifications is the school infrastructure. The schools have deficiencies in infrastructure, as less than 65% of them have a science laboratory, a space that, if well equipped and used by teachers, can contribute to student learning.

On the other hand, besides the variables analyzed in this study, there are other factors that can have a strong impact on student performance, such as the socioeconomic level of the student (Coleman et al., 1968; Carmo et al., 2014), the active participation of families in school life (Plowden, 1967; Menezes-Filho, 2007; Antonelli-Ponti et al., 2021), as well as the student's own cognitive development (Sassaki et al., 2018).

Final considerations

These results are relevant to contextualize the performance of Brazilian students in large-scale assessments, either nationally or internationally. In most cases, the blame for poor performance falls on the students and teachers, when, in fact, one should question the effectiveness of the public policies that have been adopted and the importance given to education. It is the State's duty, guaranteed by law, to provide conditions for access to a quality education. Public educational policies are constantly changing, but they are not always focused on comprehensive quality, which includes well-equipped schools, qualified teachers, and adequate remuneration in line with the social relevance of the teaching profession, across all schools regardless of type and location.

The heterogeneity of performance between school types and locations shows how much we still need to improve resource management, teacher training and qualification, as well as school infrastructure. Inequalities and the low quality of education have an impact on students' careers and education, as the ENEM score is used for university admission, and the most valued courses are highly competitive among students with the highest scores.

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NOTE:
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Data Availability
Informamos que os dados utilizados na pesquisa foram disponibilizados publicamente, e podem ser acessos por meio do Banco de dados ENEM. https://github.com/Gilvane-Gomes/Banco-de-dados-ENEM