EDUR • Educação em Revista. 2025;41;e59221
DOI: http://dx.doi.org/10.1590/0102-469859221T
Preprint: https://doi.org/10.1590/SciELOPreprints.11680

ARTICLE

DIGITAL EXCLUSION AND ITS IMPACTS ON ENEM PROFICIENCY: A STUDY OF LOW-INCOME HIGH SCHOOL GRADUATES FROM 2015 TO 2023

JORDANA APARECIDA DE OLIVEIRA RUBIM[1]
ORCID: https://orcid.org/0009-0008-7317-4112
<jormfrancis@gmail.com>
DAIELLY MANTOVANI[1]
ORCID: https://orcid.org/0000-0001-6320-3268
<daielly@usp.br>
OCIMAR MUNHOZ ALAVARSE[1]
ORCID: https://orcid.org/0000-0002-8102-1668
<ocimar@usp.br>

[1] Universidade de São Paulo. (USP). São Paulo, SP, Brazil.

ABSTRACT: This study aims to investigate the impact of household access to the internet and computers on the proficiency of low-income 12th-grade students who participated in the ENEM between 2015 and 2023. This quantitative research collected a sample of 1.5 million students that was analyzed to test hypotheses using statistical models, focusing on isolating the net effect of internet and computer access on students' scores. The study period was marked by significant changes, including the COVID-19 pandemic. The analyses provided evidence on the importance of these technological resources for students' proficiency. Additionally, the findings revealed that home internet access alone has a small yet positive impact. However, the combination of home internet and computer access leads to a significant increase in student proficiency, with even greater effects observed during and in the years following the pandemic. Variables such as gender, maternal education, and race also influenced proficiency. Female students exhibited lower performance, as did those whose mothers had lower levels of education. Conversely, white students demonstrated higher performance in the exams, reflecting the effects of social inequalities and exclusionary processes on education in the country. The results highlight that digital exclusion significantly impacts students' performance in the ENEM, suggesting that policies aimed at expanding access to technology in the home environment could have positive effects on Brazilian education.

Keywords: digital inclusion, household internet access, computer, low income, academic proficiency.

EXCLUSÃO DIGITAL E SEUS IMPACTOS SOBRE A PROFICIÊNCIA NO ENEM: UM ESTUDO COM CONCLUINTES DO ENSINO MÉDIO DE BAIXA RENDA ENTRE 2015 E 2023[1]

RESUMO: Este trabalho tem como objetivo investigar o impacto do acesso domiciliar à internet e ao computador na proficiência de alunos de baixa renda do 3º ano do ensino médio, que participaram do ENEM entre 2015 e 2023. Esta pesquisa quantitativa com uma amostra de 1,5 milhão de alunos, testou hipóteses utilizando modelos estatísticos, focando em isolar o efeito líquido do acesso à internet e ao computador na nota desses alunos. O período do estudo foi marcado por mudanças significativas, incluindo a pandemia de COVID-19, e as análises apresentaram evidências sobre como essas condições tecnológicas possuem importância para a proficiência dos alunos. Se o acesso à internet em casa, isoladamente, tem impacto pequeno, porém positivo, a combinação de acesso domiciliar à internet e ao computador resulta em um aumento significativo na proficiência dos alunos, sendo ainda maior durante e nos anos posteriores à pandemia. Variáveis como gênero, escolaridade da mãe e raça/cor também demonstraram impacto sobre a proficiência; mulheres tiveram menor desempenho, assim como estudantes cujas mães possuem menor escolaridade e, por outro lado, candidatos autoidentificados como brancos apresentaram maiores notas do que negros, o que reflete os efeitos das desigualdades sociais e dos processos de exclusão observados na educação escolar no país. Os resultados evidenciam que a exclusão digital tem impacto significativo sobre o desempenho dos estudantes no ENEM de forma que políticas para ampliar o acesso às tecnologias de informação e comunicação (TIC) no ambiente domiciliar podem ter impactos positivos sobre a educação brasileira.

Palavras-chave: inclusão digital, acesso à internet domiciliar, computador, baixa renda, proficiência escolar.

EXCLUSIÓN DIGITAL Y SUS IMPACTOS EN LA COMPETENCIA ACADÉMICA: UN ESTUDIO CON ESTUDIANTES DE BAJOS INGRESOS PARTICIPANTES EN EL ENEM ENTRE 2015 Y 2023

RESUMEN: Este estudio busca investigar el impacto del acceso domiciliario a internet y a la computadora en la competencia académica de estudiantes de bajos ingresos del último año de educación secundaria que participaron en el ENEM entre 2015 y 2023. Esta investigación cuantitativa analizó una muestra de 1,5 millones de estudiantes para evaluar hipótesis mediante modelos estadísticos, con un enfoque en aislar el efecto neto del acceso a internet y a la computadora en los puntajes de los alumnos. El período de estudio estuvo marcado por cambios significativos, incluida la pandemia de COVID-19. Los análisis proporcionaron evidencia sobre la importancia de estos recursos tecnológicos en el rendimiento académico de los estudiantes. Además, los resultados indicaron que el acceso a internet en el hogar, por sí solo, tiene un impacto pequeño pero positivo. Sin embargo, la combinación del acceso domiciliario a internet y a la computadora genera un aumento significativo en la competencia académica de los estudiantes, con efectos aún mayores durante y después de la pandemia. Asimismo, variables como el género, el nivel educativo de la madre y la raza influyeron en la competencia académica. Las estudiantes mujeres presentaron un desempeño inferior, al igual que aquellos cuya madre tenía un nivel educativo más bajo. Por otro lado, los estudiantes de raza blanca obtuvieron mejores resultados en las pruebas, lo que refleja los efectos de las desigualdades sociales y los procesos de exclusión en la educación del país. Los hallazgos evidencian que la exclusión digital tiene un impacto significativo en el desempeño de los estudiantes en el ENEM, lo que sugiere que las políticas orientadas a ampliar el acceso a la tecnología en el entorno doméstico podrían tener efectos positivos en la educación brasileña.

Palabras clave: inclusión digital, acceso a internet domiciliario, computadora, bajos ingresos, competencia académica.

---

[1] Article published with funding from the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* - CNPq/Brazil for editing, layout and XML conversion services.

INTRODUCTION

Sustainable Development Goal (SDG) 4 of the UN 2030 Agenda proposes quality education for all. However, its achievement, among other factors, is related to the opportunities and challenges posed by technology. This factor became even more evident with the COVID-19 pandemic (UNESCO, 2024), which impacted 1.6 billion students through school closures in 194 countries (Gottschaw & Weise, 2023). The pandemic suddenly forced educational institutions to adapt quickly to distance learning, facing challenges ranging from technological infrastructure to student demotivation, which increased feelings of difficulty and concern about achieving the desired learning outcomes (Sutiah et al., 2020).

Given this scenario, reflections on the importance of digital inclusion intensified, especially in the home environment, which was crucial during social isolation. As families adapted to remote learning, low-income students were disproportionately affected (Gottschaw & Weise, 2023; Gil Quintana & Vida De León, 2022; Gu, 2021; Prince Torres, 2024), as they lacked the basic conditions to participate in virtual classes, such as an internet connection, equipment, or adequate physical space. In Brazil, more than 5 million students remained isolated at home without access to remote school activities (Bauer, 2021). For these young people, the pandemic became synonymous with a rupture with the school system, as it limited access to educational content and teaching platforms, contributing to unsatisfactory performance in educational assessment exams and, consequently, in the selection processes for entry into higher education, a crucial stage for entering the job market (Izquierdo et. al., 2023).

Although some actions have been implemented to make education more inclusive, such as reviewing teaching materials, teacher training, and incorporating innovative technologies, unequal access to the internet and computers remains relevant (UN, 2024), impacting low-income groups (Boeren, 2019).

Data from the Center for Studies and Research (Cetic-*Centro de Estudos e Pesquisas*), linked to the Internet Steering Committee (CGI-*Comitê Gestor da Internet*) and considered the main source of public statistics regarding internet use in Brazil, demonstrated growth in internet access, from 58% in 2015 to 84% in 2023, and in home computers, from 38% in 2019 to 41% in 2023. However, when looking at data from class D, only 60% had daily internet access in 2022, and only 11% of households had a computer. Among class A, 93% had access in the period (Cetic, 2023), which reveals great inequality. The pandemic triggered several initiatives, accelerating the expansion of broadband access, particularly in educational institutions. The Management Board of the Telecommunications Services Universalization Fund (FUST-*Conselho Gestor do Fundo de Universalização dos Serviços de Telecomunicações*) approved an expansion through Rule 16 of April 3, 2023 (Anatel, 2023). However, a broader policy is needed, given the need to ensure access not only in schools but also in the homes of all students.

Digital inclusion can be understood as the action of providing equitable access to digital technologies and opportunities to engage with them appropriately, which includes digital literacy (Wang & Si, 2024). Conversely, digital exclusion consists of unequal access to and use of these technologies (Méndez-Domínguez et al., 2023). Prioritizing digital inclusion means ensuring that all students have essential resources, such as internet-connected devices, to allow learning to extend beyond school and into the home (Aguilar et al., 2020).

Initially, digital exclusion was studied as a restriction on access to infrastructure, the internet, and equipment, with access to these resources implying digital inclusion. However, problems of inequality persisted with the advancement of coverage in developed countries, suggesting that access alone does not result in a digitally inclusive society. In this sense, developed countries began to focus on the forms of use and the skills required for digital inclusion. Even in these countries, where internet access is widespread, the type of connection and equipment used for access is quite unequal, constituting a barrier to inclusion (Van Deursen & Van Dijk, 2015). While countries like Finland, Norway, and Denmark have high rates of digital presence, other European countries, such as Romania and Bulgaria, have much lower levels, revealing levels of inequality even within European countries (Cruz-Jesus et al., 2016).

The digital exclusion, even in a scenario of growing internet access, reveals persistent social inequalities, not only in the educational context. Lower-income users still have limited access to the internet due to the quality of access, unstable and low-speed connections, and the type of device used for access, predominantly cell phones. In rural areas, the lack of internet access makes access to banking and public services unfeasible, also making access to digital educational services inaccessible (Lasisi & Ogunsina, 2025). This limitation not only impedes educational development but also reduces opportunities for professional and cultural advancement, further increasing social exclusion (Correa et al., 2022).

In Brazil, the results of the National High School Exam (ENEM - *Exame Nacional do Ensino Médio*) serve as an indicator of academic proficiency across four knowledge areas and in writing, facilitating admission to both public and private higher education institutions. The ENEM comprises multiple-choice questions that assess the following areas: Languages, Codes, and their Technologies; Natural Sciences and their Technologies; Human Sciences and their Technologies; and Mathematics and its Technologies. Candidates' proficiency in each of these tests is measured on a scale from 0 to 1000. The essay component, which is a constructed-response item, is also scored on this same scale; however, unlike the multiple-choice tests, Item Response Theory (IRT) is not applied to evaluate this section. This study aims to determine whether low-income students in their 3rd year of high school who have access to the internet and a computer demonstrate greater proficiency in the ENEM's multiple-choice areas compared to those who do not have such access, thereby examining the impact of digital exclusion on exam performance and, consequently, on the ability of this demographic to access higher education.

In this research, digital inclusion will be considered in terms of access to digital resources (the internet and computers) in the home environment, without addressing digital literacy, a relevant aspect for the educational process. This focus is justified by the methodological approach adopted, which consists of a quantitative study based on data from the Anísio Teixeira National Institute of Educational Studies and Research (INEP-*Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira*), which does not address literacy. However, since infrastructure is crucial for literacy, the research results seek to contribute to this field by highlighting gaps in secondary education in Brazil and providing support for the development of educational policies to address these gaps.

This introductory section outlined the research context and its objective. Then, we show a literature review covering digital inclusion and specifically the relevance of internet access to this inclusion. The third section presents the research's methodological procedures, which consisted of a quantitative study with open-source data collection and statistical and computational modeling to support the research hypotheses. The fourth section presents the research results and discussions, followed by the fifth section's concluding remarks and research contributions.

LITERATURE REVIEW

Digital Inclusion and Internet and Computer Access

In the mid-1990s, amidst a wave of increasing globalization and the rapid expansion of the internet in the United States, the concept of "digital exclusion" gained prominence, highlighting how access to technology could facilitate economic and social inclusion. This viewpoint emerged for three primary reasons: the rise of a new economy centered around information and networks; the escalating significance of Information and Communication Technologies (ICT) in this evolving landscape; and the notion that access to these technologies could determine the line between exclusion and inclusion in the emerging socioeconomic era (Warschauer, 2003).

This networked society configuration brings the challenge of providing access to ICT, especially for lower socioeconomic segments, giving rise to the term "digital inclusion" (Yu, X., Liu, S., 2022; Sant'Ana et al., 2021). Not being part of the digital and technological world exacerbates inequality and social exclusion (Cooper, 2010). To ensure the effectiveness of digital inclusion, it is primarily necessary to eliminate inequalities in opportunities for technological access and connectivity to devices and networks, including the internet, to consequently develop the skills necessary to use technological resources (Morte-Nadal & Esteban-Navarro, 2022). This challenge extends to all citizens, regardless of the region where they live, whether in an urban or rural context (Gallardo, 2019). Therefore, ICTs begin to affect social structures and all domains of the social system are transformed, as the internet becomes a universal tool for interactive communication (Castells, 2000).

Connecting digitally can create spaces for discussion and knowledge exchange, and even economic activities, contributing to social and economic development (Izquierdo et al., 2023; Bustillo & Aguilos, 2022; Engelbrecht et al., 2020; Sujarwoto & Tampubolon, 2016; Koutroumpis, 2009).

Specifically at the educational level, access to these technological resources has become vital for successful participation in society (Goldhammer et al., 2016), as staying connected and constantly studying (lifelong learning) has become a mandatory task for those who want to maintain sustainable qualifications for the academic or professional market.

However, inequality in access to the internet and equipment has been an obstacle even in developed countries, leading to different levels of technological skills, with those who use the internet for any purpose developing greater computer skills (Lei & Zhou, 2012). From a different perspective, mere internet access will not guarantee meaningful use of the resource; sociodemographic variables influence usage, and, for example, lower-income people tend to use the internet for entertainment, while higher-income people access more informative and educational portals (Zhang, 2015). A study conducted between 2005 and 2016 in Italy showed that access to technologies such as the internet and computers increased over time, but inequality between different segments of the population persisted, especially in the southern region of the country and among families with less educated heads of households (Di Pietro, 2021). Thus, the variables region and the head of household's education level emerge as relevant for understanding the processes of digital exclusion. Urban or rural location and home infrastructure are also relevant (Gu, 2021; Kartiasih et al., 2023), as is family income (Rajam et al., 2021). In developing countries, the expansion of cell phones and smartphones increases the number of users with internet access. However, data from Indonesia showed that other variables, such as educational level, age, and income, determine the use of this resource. More educated, higher-income, and younger people are those who actually access the internet. That is, although a broader study population had access, they did not use it (Puspitasari & Ishii, 2016). At the country level, a relationship between education level and internet use is also observed, with countries with families whose parents are educated having more widespread and significant internet use (Billon et al., 2021). Gender inequality is also relevant in assessing the digital divide, with women being the greatest victims (Adeleke et al., 2022). Considering the nature of internet use, a study conducted in 29 European Union countries demonstrated that access to digital services is related to education level, while recreational use is related to user age (Elena-Bucea et al., 2021). However, the influence of sociodemographic factors was shown to be inconsistent in a study conducted in Asian and African countries on internet use on mobile devices (Vimalkumar et al., 2021).

Bandwidth is an important factor to consider. Although internet access may have increased, there is persistent inequality in terms of the quality (availability and speed) of the service consumed across regions (Hilbert, 2016). Another point observed is that the type of internet access influences equitable and true digital inclusion. A study conducted in Chile between 2018 and 2020 showed that people who use both cell phones and computers develop more significant digital skills over time, compared to those who use only mobile devices. The use of mobile devices, while expanding internet access because they are easier to acquire, can limit the digital skills acquired, as activities performed on these devices tend to be more restricted, while on computers, engagement tends to be broader and more sophisticated (Lima & Araújo, 2021; Correa et al., 2022). Access to the internet via cell phones and tablets does not reduce digital exclusion, as inclusion would imply full access to the different digital systems available, from social networks to public health and education services, and interaction with these systems is optimized, or sometimes possible, only via computers, evidencing social stratification (Faith & Hernandez, 2024).

A study conducted in southern Brazil found that having a home computer can reduce school failure, but internet access can demotivate and distract students (Reed & Reay, 2015). The impacts of technology go beyond academic performance; a study of Chinese students showed that those with internet access at home scored higher than those without it on computer and internet self-efficacy, attitudes toward technology, and learning (Lei & Zhou, 2012), highlighting the multidimensionality of the topic.

Importance of ICT in the teaching and learning process

ICT has driven the creation of educational content and distance learning platforms (Hermida & Bonfim, 2006). Over the years, new ways of distance learning have been created, using the internet as a means of making educational content available and interacting, such as Moodle in 2001, OCW - Open Course Ware in 2002, Khan Academy in 2008 (a non-governmental organization that produces and distributes educational videos over the internet), YouTube Edu in 2009 which provides online lectures, Udemy, Udacity and Coursera, digital platforms that offer massive online courses and are becoming popular among students and professionals (Filatro, 2022).

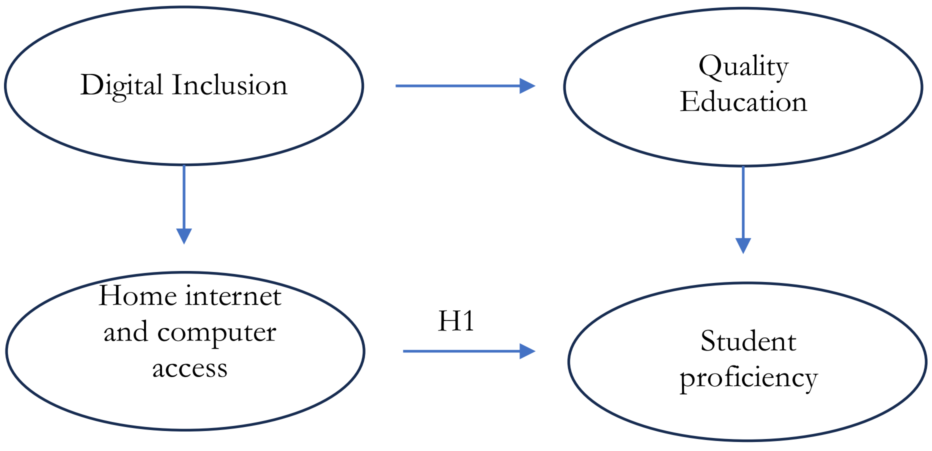
ICTs are seen as allies in the classroom (Engelbrecht et al., 2020) because they make classes more engaging and enable more independent learning. Students can quickly access up-to-date information through automated search engines that aid the teaching and learning process and make classes more meaningful and engaging (Lima & Araújo, 2021). Many institutions and teachers do not use ICT in their classes. Although there is great potential, adequate implementation in schools still faces many challenges, such as a lack of equipment, teacher training, and a lack of perspectives on how to use it to ensure students understand the significance of technological adoption in the educational context (Almeida et al., 2023).

While there are numerous benefits to integrating technology in education, a significant challenge lies in adequately preparing teachers to adapt their pedagogical approaches and effectively incorporate these new tools. Ongoing professional development for educators is essential for the successful use of Information and Communication Technology (ICT) and plays a key role in fostering students' cognitive development (Lima & Araújo, 2021). It is crucial to equip teachers with the skills to utilize technology, transforming them into knowledgeable mediators who can navigate the complexities of the school environment and establish guidelines that extend beyond the classroom. With the incorporation of ICT in the learning space, a notable shift occurs: students take on a more autonomous role, enhancing their critical thinking abilities, while teachers transition into facilitators of the learning process (Costa et al., 2019).

A study of internet use conducted with 140 children by the Black Child & Family Institute concluded, after six months, that children who used the internet more scored higher on standardized reading achievement tests than those who used it less (Jackson et al., 2006). Another study, with students from the Murcia region of Spain, assessed the perception of 2,734 secondary school students regarding the benefits of the internet for their educational learning, and 68% perceived benefits. Most of the sample mentioned that they believed teachers should use the internet more in class, as the use of visual resources, such as videos, facilitates learning. On the other hand, the 32% of students who did not perceive internet use in class as beneficial believe that it can distract them and hinder their progress on homework, causing them to lose focus. This study also concluded that low-income families make less use of computers and the internet, reinforcing the urgency of digital inclusion to reduce inequality (Pagán et al., 2018).

The urgency of addressing inequality in access to technology becomes greater with Artificial Intelligence (AI), which is present in daily tasks (Balaban et al., 2023; Choi et al., 2023). AI is a subject of research in educational studies, addressing topics such as the potential downsides of using these technologies, personalization; risks and benefits of use; best practices for students and teachers; among other topics. Given the above, it is clear that the application of ICT has evolved significantly in recent decades, in different spheres, especially in education. However, discussing the applications of Artificial Intelligence, robotics, and personalization is complex when underlying problems, such as restricted access to technological infrastructure, still persist. Therefore, considering the study objective and the literature reviewed, the conceptual research model is proposed (Figure 1).

Figure 1 - Conceptual Research Model



This is reinforced by the studies of Jackson et al. (2006), Lei and Zhou (2012) and Pagán et al. (2018), which sought to understand the influence of internet access on the development of students' skills, as well as identify its benefits for educational learning, hypothesis H1a is proposed:

Hypothesis 1.a: Having home internet access positively influences student proficiency.

The literature suggests that home internet access can increase exposure to varied and up-to-date educational content, allowing students to study and prepare better, and consequently be better prepared for exams such as the ENEM (National High School Exam). Furthermore, internet access facilitates the acquisition of knowledge and skills, as well as improving students' self-confidence in meeting academic demands (Lei & Zhou, 2012; Correa et al., 2022). The type of access device (cell phone or computer) influences student outcomes (Damiani et al., 2016; Araujo, 2019), with greater gains in the development of digital skills among students who combined use of a computer and cell phone than those who used only a cell phone, considering that computer access offers a more robust study environment, allowing the use of educational software and platforms and the performance of more complex activities that would not be possible using a cell phone (Lei & Zhou, 2012; (Correa et al., 2022; Jackson et al., 2006). Thus, hypothesis H1b is proposed.

Hypothesis 1.b: Having home access to the internet and a computer enhances student proficiency.

Finally, to determine whether these technologies are important and lasting factors over time for the target audience—low-income students in their final year of high school—hypothesis H1c is proposed:

Hypothesis 1.c: Having home access to the internet and a computer is a relevant factor, compared to other variables, year after year, for student proficiency.

METHODOLOGICAL PROCEDURES

To achieve the objective of this study—to determine whether home internet and computer access influence low-income high school students' proficiency on the ENEM, the research population was defined as individuals who registered for the exam, attended both days of administration, and scored on all four objective tests. The data were obtained from results published by INEP, which included, in addition to proficiency scores, responses to the questions on the registration questionnaire from 2015 to 2023. The time series began in 2015, as from that year onward, the exam registration questionnaire standardized some questions, particularly questions Q024 (computer access) and Q025 (home internet access), allowing for comparison of data between the years considered.

During the investigated period, there were over 49 million registrations for the ENEM, totaling 49,839,303. Out of these, approximately 33 million participants, specifically 33,295,732, completed the four objective tests. Records with missing information were excluded, which did not significantly affect the distribution of the variable means, resulting in 32,601,016 valid entries. Among these, around 10 million participants (10,366,389) were in their final year of high school, with half of them coming from families with an income of less than or equal to 1.5 minimum wages. This low-income population, totaling 5,148,898 students, is the primary focus of this research. Given the substantial amount of data, a random sample of 30% was selected from the low-income participants in their final year of high school, amounting to 1,544,670 graduating students. Outliers in student scores, constituting approximately 1% of the sample, were disregarded, resulting in 1,529,177 valid scores. By concentrating on students in their final year of high school, this sample aims to reduce biases compared to other profiles participating in the test, such as those taking practice exams, those who have already graduated, or those who did not complete high school and were not enrolled at the time of the exam.

The statistical analyses performed used the Python computing environment. During the data preparation phase, observations with missing values were excluded. Due to the new guidelines of the General Data Protection Law (LGPD-*Lei Geral de Proteção de Dados*), starting in 2020, INEP stopped publishing the variable "state of residence" (the Federal Unit where the candidate resides). Therefore, for 2020 to 2023, the state of residence was estimated using the variable "state of the test location." From this, the variable REG_UF was created to indicate the region of residence (North, Northeast, South, Central-West, Southeast).

For categorical variables such as gender, region, type of school, race/color, parental education, home infrastructure, and family size, among others, binary dummy variables were created (0 = absence of the attribute and 1 = presence of the attribute), as recommended by Géron (2017). Furthermore, binary descriptive variables of interest to answer the research questions were created as follows:

- I: 1 if the participant has home internet access, 0 if not;
- C: 1 if the participant has access to a computer at home, 0 if not;
- SóI: 1 if the participant has internet access but does not have a computer at home, 0 if not;
- SóC: 1 if the participant does not have internet access and has a computer at home, 0 if not;
- IeC: 1 if the participant has internet access and has a computer at home, 0 if not.
- nIenC: assumes 1 participant has neither a computer nor internet access at home, 0 if not;

This binary variable, IeC, can provide insights into the type of equipment a participant uses to access the internet. For example, if a participant has both a computer and internet access, this may indicate that they use the computer to access the internet. According to Damiani et al. (2016) and Araujo (2019), the type of device used to access the internet is a relevant aspect for analyzing test performance, noting that computer use was associated with lower school failure rates.

Finally, to define a dependent variable representing student proficiency for applying the statistical models of this study, the variable NU_MEDIA was created, calculated as the arithmetic mean of the scores on the four tests:

- NU_NOTA_MT: grade in Mathematics and its Technologies;
- NU_NOTA_CH: grade in Human Sciences and its Technologies;
- NU_NOTA_LC: grade in Languages, Codes, and their Technologies;
- NU_NOTA_CN: grade in Natural Sciences and its Technologies.

The complete list of variables analyzed in the study can be found in the supplementary material. In the data analysis, predictive models based on linear regression were developed, with the response variable (y) being the average scores of students on the four objective-level ENEM exams (NU_MEDIA). The explanatory or independent variables (x) included factors related to access to technology (computer and internet), as well as sociodemographic aspects such as gender, parental education, region of residence, race/color, type of school (public or private), family size, and home infrastructure. Home infrastructure was deemed incomplete if the residence lacked at least a microwave, washing machine, refrigerator, bathroom, and two bedrooms. The Variance Inflation Factor (VIF) was calculated to assess the presence of multicollinearity among the independent variables in the linear regression model. No such issues were detected, as all variables exhibited values below four, indicating a strong adherence to the model.

Initially, a linear regression model was applied using the ordinary least squares method to each year of the data series, estimating a linear function of the type $y = b_0 + b_1 x_1 + \ldots + b_i x_i$, where b_0 is the model constant, or vertical intercept, b_1 represents the slope, demonstrating the relationship between x and y, and x_1 is the value of the independent variable 1. This model aimed to identify whether the access variables (sóI, sóC, and IeC) and sociodemographic variables had a linear relationship with the students' ENEM results. Next, a linear regression model with panel data was applied to the explanatory variables of access (sóI, sóC, and IeC) and gender, maintaining the other sociodemographic variables as control variables. The fixed-effects model is an extension of linear regression applicable when there are specific groups, individuals, or units in which the effects are to be controlled. One way to implement this approach is by incorporating dummy variables, transforming them into binary variables (0 = absence of the attribute or 1 = presence of the attribute). These dummy variables allow the model to control for fixed individual or group effects, capturing the specific variation associated with each unit or group. By including fixed effects, it removes the influence of constant individual or group characteristics, focusing on the variation between individuals. In the problem at hand, each year has a different set of students taking the ENEM (National High School Exam), meaning there are no repeated observations over time for the same individuals. Thus, independent models were created for each year to compare results and account for the factors that influence student scores over time. The aim was to neutralize the effect of socioeconomic context on exam scores by controlling the estimates for the number of people living in the same household, parental education, racial differences, and other socioeconomic characteristics. Once the effect of the variables for race/color, gender, region, type of school attended, mother's and father's education, family size, and home infrastructure are controlled, the remaining effect found in the parameters of the technology access variables can be interpreted as the closest effect that home access to the internet and computers has on students' grades.

From a methodological perspective, this research employed statistical models, including ordinary least squares (OLS) linear regression and fixed-effects models, to estimate associations and potential impacts of specific variables on the analyzed educational outcomes. It is crucial to acknowledge the particularities and limitations of these approaches within the field of Social Sciences and Humanities. While these models facilitate statistical control over some observable heterogeneity and, in certain instances, allow for the isolation of conditional effects, they do not entirely resolve issues related to endogeneity, the omission of relevant variables, or selection bias. Moreover, the use of the term "impact" must be approached with caution; in the absence of a rigorous experimental or quasi-experimental design, such inferences cannot be regarded as causal in a strict sense. Therefore, "impact" should be understood as an indication of statistical significance. In the context of education and the humanities, the complexity of social phenomena necessitates the integration of qualitative approaches to gain deeper insights into the meanings, processes, and contexts involved, which often elude quantitative metrics. Consequently, it is acknowledged that the statistical models employed here provide a pertinent yet limited analytical approximation of the educational reality being investigated.

RESULTS

Considering the sample of low-income students, we observed that the majority come from the Northeast region (45%), followed by the Southeast (27%), North (13%), and South and Central-West (7% each). In terms of race/color, there is a predominance of brown (54%), followed by white (27%), black (14%), Asian (2%), and indigenous (2%). The majority of students are women (63%), and 93% attended public high schools. The maximum family income is 1.5 minimum wages, with 52% having a family income of up to one minimum wage, 40% between one and 1.5 minimum wages, and 8% having no income. Regarding parents' education, 34% had mothers with incomplete elementary education, 34% with completed high school, and 17% with completed elementary school; only 7% of mothers had higher education, and 3% had never attended school. From the fathers' perspective, 41% of students had fathers who had incomplete elementary education, 23% had completed high school, 14% had completed elementary school, only 4% had higher education, and 6% had never attended school. It is noteworthy that 5% of mothers and 13% of fathers did not know their children's educational level, which may suggest that the students live with other family members or guardians other than their parents. In terms of home infrastructure, 78% of students reported living in a home with incomplete infrastructure, that is, with less than one bathroom, two bedrooms, a microwave, a washing machine, and a refrigerator. Regarding family size, students live in 51% of households with families of 3 to 5 people, 35% with families of fewer than 3 people, and 14% with families of more than 5 people.

First, multiple linear regression was applied as an initial approach to assess the significance of computer and internet access, holding the other variables constant. The first model considered only the technology access variables (sóI, sóC, and IeC), with general equation 1.

$$y = b_0 + b_{sói}x_{sói} + b_{sóc}x_{sóc} + b_{iec}x_{iec}, \quad \text{where,} \tag{1}$$

y = student's average score on the Enem exams

b_0= constant, vertical intercept, that is, the value of y when the other variables have a value of zero.

$b_{sói}$= angular coefficient for the variable sóI (internet access)

$b_{sóc}$ = slope for the variable sóC (computer access)

b_{iec}= cangular coefficient for the variable IeC (internet and computer access)

x= independent variables onlyI, onlyC and IeC

Table 1 shows the regression coefficients for the model's explanatory variables. Positive coefficients indicate that the presence of ICT resources increases the average ENEM score. In all years of the time series, access to ICT positively influences student performance on the exam.

Table 1 - Result of the model with the variables of interest: sóI, sóC and IeC

Variables	Year								
x	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intercept	461.71***	467.32***	470.82***	486.99***	462.49***	458.18***	451.31***	465.31***	462.64***
sóI	8.36***	9.59***	10.71***	10.81***	10.64***	13.51***	13.52***	14.51***	14.76***
sóC	16.67***	16.50***	19.14***	19.69***	21.61***	30.61***	24.39***	18.90***	24.09***
IeC	23.10***	24.97***	28.28***	29.12***	32.32***	40.96***	41.08***	39.11***	41.58***

Notes: *** p-value < 0.01; ** p-value <0.05; *p-value<0.1

The results demonstrate that, without considering the effect of sociodemographic variables, all access variables were significant (p-value < 0.01); these variables have a statistically significant effect on the model's dependent variable (Enem score). The coefficients represent the increase in points in the students' average score, always considering all other variables constant. For example, in 2015, if a student had only internet access (sóI = 1) and the other variables were equal to zero, there would be an increase of 8.36 points in the Enem average.

A second linear regression model was estimated, considering not only the access variables but also the students' sociodemographic variables, as shown in equation 2.

$$y = b_0 + b_1x_1 + \cdots + b_{23}x_{23}, \quad \text{where} \tag{2}$$

y = average student score on the Enem exams

b_0= constant, vertical intercept, that is, the value of y when the other variables have a value of zero.

$b_1\ to\ b_{23}$= angular coefficients of variables 1 to 23

Table 2 shows the regression results, focusing on the coefficients of each variable and their statistical significance. The interpretation of the coefficients associated with each variable is the number of points that variable adds to the student's grade, assuming all other variables remain constant. Regarding gender, being female is associated with a reduction in grades, with female students showing, on average, lower proficiency on the exam over the nine years. This result is in line with previous analyses and studies by Monteiro (2022), Moraes et al. (2022), and Dutra et al. (2023).

By region, students in the Southeast and South regions perform better than the North, which serves as the reference region. The coefficients for the Southeast in 2023 suggest that students living in this region achieve, on average, 21.47 points more than students in the North, and students in the South, 17.32 points more, which is consistent with the literature that highlights digital inequality in rural and remote regions (DiPietro, 2021; Gu, 2021; Kartiasih et al., 2023).

The type of school attended has proven to be significant, as students in public schools consistently demonstrate lower proficiency scores compared to their counterparts in private schools. This finding aligns with the research conducted by Feijó and França (2021), which underscores the disparities between public and private education and highlights the increasing influence of family background in mitigating these inequalities. Within the family context, factors such as parental education and family size have shown notable impact. Feijó and França (2021) further indicate that the influences of class, teachers, and the school environment have become less critical in explaining performance differences, thereby allowing individual attributes—particularly family background—to take on a vital role in elucidating performance inequalities.

The higher the parents' education level, especially the mother's, the higher the student's average grade. The coefficient for the variable "Mae_ESup_mais" (mother with higher education or more) was 16.91 points in 2015 and increased to 23.78 in 2023. This increase suggests that the mother's education level began to have an even greater influence on the student's grade, expanding the understanding of this issue, initially reported in the work of Feijó et al. (2022), who assessed the net effect of the contribution of parents' education on their children's education in 2017. Like gender and type of school, family size also impacts grades, with the larger the family, the greater the negative impact on the student's average grade.

Considering the technology access variables, the variable "sóI" (access only to the internet) was statistically significant in all years, with a 2.13-point increase in grades in 2015 and 6.55 points in 2023, suggesting a positive impact on student performance. Although significant, the impact of "sóI" is smaller than that of "IeC," suggesting that having only internet access contributes less to student grades.

For the variable "having access to the internet and a computer at home" (IeC), there was a significant and growing impact on grades, especially during the COVID-19 pandemic, with coefficients exceeding a 20-point increase in ENEM scores, reaching 23.38 in 2021. This demonstrates the importance of these technologies for academic performance (Jackson et al., 2006; Correa et al., 2022). Table 2 contains this data set.

Table 2 - Results of the model with all explanatory variables

	Variables	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Intercept	477.70***	485.97***	488.38***	483.99***	478.37***	476.80***	463.30***	469.68***	468.13***
Internet and computer Ref: nIeNC	SóI	2.13***	3.50***	4.13***	4.22***	3.60***	5.64***	6.59***	7.00***	6.55***
	SóC	10.24***	9.91***	11.42***	11.06***	12.66***	18.99***	15.57***	10.09***	12.62***
	IeC	11.47***	13.19***	14.87***	15.23***	16.46***	20.54***	23.38***	20.58***	20.09***
Gender Ref: male	Female	-7.63***	-10.05***	-8.79***	-8.88***	-8.40***	-17.15***	-11.39***	-8.63***	-9.07***
Race Ref: race_other	White	5.32***	5.30***	5.78***	7.18***	8.97***	12.28***	11.49***	12.28***	14.71***
	Brown	0.40	0.38	0.30	0.47	0.91***	2.85***	2.25***	2.07***	3.02***
Region Ref: North	Midwest	4.56***	3.97***	6.74***	4.47***	7.17***	7.80***	5.43***	5.09***	7.78***
	Northeast	4.91***	5.05***	5.34***	5.49***	7.13***	7.22***	9.54***	8.83***	7.87***
	Southeast	12.20***	10.90***	13.26***	12.93***	14.45***	19.12***	19.38***	20.32***	21.47***
	South	11.49***	9.20***	12.31***	10.34***	13.58***	18.53***	14.84***	13.41***	17.32***
Type of school Ref: escpartic	escpubl	-28.18***	-28.01***	-29.96***	-10.80***	-32.26***	-31.37***	-28.14***	-24.81***	-31.85***
Mother's education Ref: unknown_mother	Mae_elem_incompl	6.48***	5.49***	6.35***	6.64***	7.16***	9.42***	8.23***	8.91***	9.86***
	Mae_elementary	9.83***	8.78***	9.61***	10.91***	11.07***	13.75***	11.22***	12.63***	14.90***
	Mae_highschool	14.53***	13.94***	14.01***	15.77***	16.60***	18.58***	15.84***	18.10***	20.99***
	Mae_higher_ed	16.91***	16.02***	16.80***	19.51***	19.99***	22.10***	16.66***	20.09***	23.78***
Father's education Ref: unknown_father	Pai_fund_incompl	0.48	0.33	1.30***	0.57*	1.45***	-0.26	-0.22	0.56	1.06
	Father_elementary	2.82***	3.22***	3.45***	4.33***	3.97***	2.96***	3.15***	3.20***	3.55***
	Father_highschool	6.58***	6.78***	7.53***	7.59***	8.26***	5.99***	5.97***	6.80***	7.99***
	Father_higher_ed	13.93***	12.76***	14.24***	16.46***	15.13***	14.76***	11.86***	12.39***	15.25***
Family size Ref: tam3pessoaspeq	Size5medperson	-3.70***	-3.28***	-3.50***	-3.70***	-4.39***	-4.29***	-4.21***	-4.86***	-5.41***
	Size6bigperson	-8.39***	-8.00***	-8.69***	-8.81***	-8.90***	-9.68***	-9.81***	-10.07***	-11.42***
Home Infrastructure ref: infra_basiccomplete	Infra_basicincomplete	1.23***	1.00***	1.49***	0.42	1.67***	0.95***	2.72***	3.73***	6.06***
Low income Ref: income_0to1	Income1.5	6.97***	6.59***	7.35***	8.06***	7.86***	10.87***	9.66***	11.18***	12.88***

Notes: x1 sóI; x2= sóC, x3= IeC; x4= female, x5 = white race; x6 = brown race; x7 = central-west region; x8 = northeast region; x9 = southeast region, x10 = south region; x11 = public school; x12 = mother's education: incomplete elementary school; x13 = mother's education: complete elementary school; x14 = mother's education: high school; x15 = mother's education: higher education; x16 = father's education: incomplete elementary school; x17 = father's education: complete elementary school; x18 = father's education: high school; x19 = father's education: higher education; x20 = average family size; x21 = large family size; x22 = incomplete basic household infrastructure; x23 = income greater than 1.5 minimum wages. Ref: reference category, which receives the code zero in the modeling

A fixed-effects regression model was applied, one for each year, to understand the gross and net influence that access to technology (computer and internet) at home has on the dependent variable. Initially, only the technology access variables and the gender variable (female=1) were introduced as explanatory variables to assess the effect of gender differences on performance; the other demographic variables were not considered in the model, as was done in the study by Feijó et al. (2022). Equation 3 is the estimated regression for this model.

$$y = b_0 + b_{sói}x_{sói} + b_{sóc}x_{sóc} + b_{iec}x_{iec} + b_{fem}x_{fem} \quad (3)$$

The coefficients of each variable of interest in each year estimate how much each variable increases the student's average grade when compared to the student who does not have internet or a computer (nIenC) in that year, as shown in Table 3. Without evaluating the effect of the other variables, it is noted that all of them have a significant p-value, with having internet and a computer or just internet increasing the student's performance, while being female reduces the grade in all years, which highlights gender inequality (Adeleke et al., 2022).

Table 3 - Effect of internet and computer access on average grade, without control

Variables x	Ano								
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intercept	466.5***	473.61***	476.25***	492.36***	467.67***	469.39***	458.31***	470.42***	467.95***
sóI	8.46***	9.68***	10.77***	10.89***	10.67***	13.51***	13.66***	14.53***	14.59***
IeC	22.87***	24.55***	27.86***	28.65***	31.81***	39.79***	40.59***	38.68***	40.85***
Female	-7.41***	-9.77***	-8.49***	-8.35***	-8.01***	-16.83***	-10.93***	-7.79***	-7.91***

Note: *** p-value < 0.01; ** p-value <0.05; *p-value<0.1

The fixed effects model was then estimated considering the same explanatory variables (gender and access variables), but adding the effect of the sociodemographic control variables (Equation 4).

$$y = b_0 + b_{sói}x_{sói} + b_{sóc}x_{sóc} + b_{iec}x_{iec} + b_{fem}x_{fem} + \text{Wi} \quad (4)$$

Where:

y= is the average score on the four objective tests of individual i, with fixed effects Ωi;

$b_{sói}$ = is the regression coefficient indicating the net effect of the individual having only internet access at home;

$b_{sóc}$= is the regression coefficient indicating the net effect of the individual having only a computer at home;

b_{iec}= is the regression coefficient indicating the net effect of the individual having internet access at home and owning a computer;

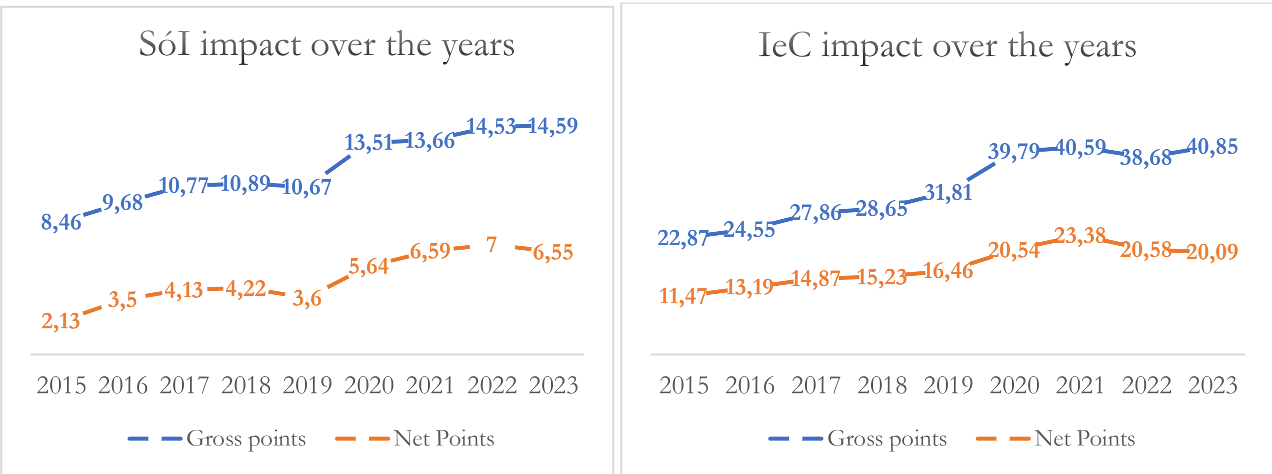
Ωi = is a set of individual fixed effects, Ωi = (νr + πs + ρo + δe + λm + φp + τf + ωu) are the fixed effects of individual i of race r, sex s, resident in region o, student at school type e, whose mother has m education level, and whose father has p education level, with family size f and home infrastructure u, on the average score;

As in the previous model, access to ICT is statistically significant in the period considered in the time series, with a positive influence on the grade. By including the gender variable, it is observed that being female reduces test performance, which reinforces the problem of gender inequality. We sought to identify the net effect of technology access variables, isolating the effect of sociodemographic variables. Taking 2020 as an example, the student who had access to a computer and internet at home (IeC) scored an average of 20.54 points higher than the student who did not have internet or a computer (nIenC). Meanwhile, the student who only had internet access scored an average of only 5.64 points higher.

Comparing the gross and net effects, students who had access to the internet and a computer (IeC) consistently scored higher over nine years than those who had neither, with a more significant increase in 2021, of 23.38 points.

Those who had only internet access and no computer at home (SóI) scored higher than those who did not have both (nIenC), but the difference was less significant, with 2022 being the year with the largest difference, reaching 7 points. Over the years, there was a gradual increase in the net effect of the internet and computer (IeC) on student scores, particularly since 2020. Figure 2 shows that technological resources affect students' ENEM results, with the net effect being that which discounts the effect of other control variables (gender, parental education, etc.). thus, it can be seen (figure on the left) that access to the internet only (6.54 points more for the student who has this resource) has an important effect; however, for the internet and computer, the effect is even more relevant (20.09 points more for students who have both resources at home) (figure on the right).

Figure 2 - Comparison of the gross and net effect of having internet and internet and computer on the average Enem score



The research hypotheses can be evaluated as presented in Chart 1. Statistical analyses, examining the average results of the ENEM exams, indicate that students who have access to technology in their homes perform better. Consequently, hypotheses 1a, 1b, and 1c have been validated. These findings underscore the importance of educational policies aimed at enhancing infrastructure in schools, while also promoting efforts to develop improved conditions in the home environment. The digital divide, defined as the net effect of access to the internet, a computer, or both, reveals that low-income students lacking these resources face significant disadvantages when compared to their peers with access, resulting in inequities even within this demographic. Although the study did not explore other income classes, it can be inferred that the disparities would likely be even more pronounced in those groups, consequently worsening social inequality and exacerbating the existing challenges within Brazilian society.

Chart 1 - Examination of research hypotheses

Hypothesis	Result
H1.a: Having home internet access positively influences student proficiency.	Proven
H1.b: Having home access to the internet and a computer enhances student proficiency.	Proven
H1.c: Having home access to the internet and a computer is a relevant factor compared to other variables, year after year, for student proficiency.	Proven

FINAL CONSIDERATIONS

The main objective of this study was to investigate how internet and computer access influence the proficiency of low-income students in their third year of high school. Proficiency was calculated as the average score on the four objective-based ENEM (National High School Exam) exams, for a sample of 1.5 million students between 2015 and 2023.

Literature suggests that internet access at home can increase exposure to varied and up-to-date educational content and, additionally, allow students to study and prepare better for exams, such as the ENEM (National High School Exam), thereby achieving better academic proficiency. It also improves students' self-confidence in meeting academic demands, as mentioned in the studies by Lei and Zhou (2012) and Correa et al. (2022). However, the research results reveal that there are many inequalities and challenges related to the use of these technologies in Brazil.

To answer the research question, three hypotheses were analyzed regarding the impact of home access to technologies, such as the internet and computers, on the proficiency of low-income students on the ENEM (National High School Exam). First, we sought to understand the isolated effect of internet access. Then, we analyzed the effect of both the internet and computers. Finally, we also analyzed the impact of these two technological resources over time. In all cases, we identified evidence of the positive impact of technology on student proficiency.

After controlling for the effect of other variables, we obtained the net effect of the condition "having internet access and not having a computer at home" compared to the condition "not having internet access or a computer." The net effect decreased significantly compared to the gross effect, falling from 14.6 to 6.6 points in 2023, indicating that the influence of other variables is relevant to the score. Nevertheless, this condition exerts a positive effect when compared to the condition of not having internet or computer access, and remains positive throughout the analyzed period.

Internet access alone is not the most significant variable in explaining the score. This suggests that having internet access at home alone does not appear to be sufficient to promote substantial improvements in student proficiency on the ENEM. However, access to both the internet and computer resources is the most relevant variable. When calculating the net effect of the condition "having internet access and a computer at home," controlling for the effects of the other variables, a positive and significant relationship is observed across all years. In 2023, although more than 84% of Brazilians aged 10 and over had internet access, only 41% accessed the internet via computer, and among the study population, this percentage was 23% (Cetic, 2024).

The significance of home internet and computer access remained substantial from 2015 to 2023, even after accounting for various socioeconomic factors. By 2021, the net effect of having both internet access and a computer at home on student grades was particularly pronounced, with students benefitting from these resources scoring an estimated 23.4 points higher than their peers without either device. During the pre-pandemic period of 2015 to 2019, the average net effect was 14.2 points, which increased to 21.2 points in the post-pandemic period. Furthermore, the analysis confirmed that the importance of these resources remained high, consistently ranking among the top factors influencing grades in six out of the nine years studied. Notably, the only exception occurred in 2019, 2020, and 2023, where the relevance of gender was found to have a greater impact on academic performance.

Women are more likely to take the ENEM in less favorable socioeconomic contexts than men. In general, they obtain lower grades and have less access to digital technologies, which adds complexity to the problem, as in addition to the digital divide, there is also the effect of gender inequality.

Internet access only via cell phones can limit engagement when the purpose of access is academic (Damiani et al., 2016), and policies that encourage not only internet access at home but also access to more suitable devices for studying, such as computers, are relevant for this population. The availability of better computing resources increases digital inclusion and can ensure the development of digital skills, so necessary in this increasingly connected society, where Artificial Intelligence (AI) is the main focus.

Through AI, professions will need to adapt, and many new products and services will emerge, including in the educational field. AI can exponentially enrich the learning experience by creating personalized educational content that meets the individual needs of each student. For example, AI algorithms can analyze student performance in educational activities and automatically generate tailored materials to strengthen areas where students have specific challenges. Therefore, given this digital and technological reality, policies must be implemented to ensure equitable access to these resources, promoting equal educational opportunities and helping to reduce socioeconomic inequalities in the genuine pursuit of achieving SDG 4, quality education, of the UN 2030 agenda.

Regarding the limitations of this work, it is worth noting that the starting point for this study was the information obtained from the INEP questionnaire administered to ENEM applicants. Most of the available variables were associated with the family's socioeconomic background, the individual's own characteristics, and the type of school (public or private). However, starting in 2020, the General Data Protection Law (LGPD) came into effect, establishing rules for the processing of personal data by companies and entities, to protect citizens' privacy and ensure the security of their personal data. Therefore, the information that INEP made available in its databases identifying the school attended by the student was omitted to prevent possible identification of the student by cross-referencing this information. Regarding the individual, motivational issues, which can lead to greater or lesser engagement in studies, were also not taken into account. There is literature suggesting that motivational aspects impact performance (Dutra et al., 2023), and these aspects should be identified and studied in depth in future research.

Other factors that may contribute to exam proficiency are suggested for future studies, such as understanding internet access in terms of network quality; the quality of student computer use, to determine whether some distinct digital capabilities and skills may lead to unequal use (digital literacy); and understanding motivational factors for having a computer at home, which may lead to greater or lesser engagement in studies.

Furthermore, a qualitative approach with interviews could be applied, considering students and school professionals, as a way to gain an in-depth understanding of why home access to ICT is so important and how it can be leveraged to improve educational development in the country. Such interviews could also generate recommendations for questions to be incorporated into the ENEM registration form to collect this data and address some of these gaps.

This work contributes to the literature by providing analytical evidence on the importance of access to technology in the proficiency of low-income students, based on a sample of 1.5 million students, which is representative of the population, and can serve as a basis for future research and public policy. Furthermore, it highlights that ensuring internet connectivity and adequate devices is crucial to providing equal opportunities for low-income students, minimizing learning delays.

REFERENCES

Adeleke, R., Iyanda, A. E., Osayomi, T., & Alabede, O. (2022). Tackling female digital exclusion: Drivers and constraints of female Internet use in Nigeria. African Geographical Review, 41(4), 531–544. https://doi.org/10.1080/19376812.2021.1963296

Aguilar, S. J., Galperin, H., Baek, C., & Gonzalez, E. (2020, October 14). When school comes home: How low-income families are adapting to distance learning. https://doi.org/10.35542/osf.io/su8wk

Almeida, L. M., Torres, C. I. O., Seixas, N. R. M., Santos, D. B., & Silva, C. D. D. (2023). A importância das tecnologias da informação e comunicação no processo de ensino e aprendizagem em ciências. Ensino de Ciências e Tecnologia em Revista, 13(1), 54-71.

Anatel (2023). Projetos Fundo de Universalização dos Serviços de Telecomunicações (FUST). Disponível em https://informacoes.anatel.gov.br/paineis/infraestrutura/projetos-fust.

Araujo, M. H. (2019). Evidenciando as desigualdades digitais: uma análise da influência da autonomia de uso e habilidades digitais no aproveitamento de oportunidades online. Tese Doutorado. Universidade de São Paulo, São Paulo.

Balaban, I., Rienties, B., & Winne, P. (2023). *Information Communication Technology* (ICT) *and Education. Applied Sciences*, 13(12318).

Bauer, A. (2021). Avaliação da Aprendizagem no contexto da pandemia. Centro de Estudos e Pesquisas em Educação, Cultura e Ação Comunitária (CENPEC), 1-16.

Billon, M., Marco, R., & Lera-Lopez, F. (2021). Do educational inequalities affect Internet use? An analysis for developed and developing countries. Telecommunications Policy, 45(10), 101521. https://doi.org/10.1016/j.tele.2020.101521

Boeren, E. (2019). *Understanding Sustainable Development Goal (SDG) 4 on "quality education" from micro, meso and macro perspectives.* International Review of Education, 65(2), 277–294.

Bustillo, E., & Aguilos, M. (2022). *The Challenges of Modular Learning in the Wake of* COVID-19: *A Digital Divide in the Philippine Countryside Revealed.* Education Sciences, 12(7), 449, 1-16.

Castells, M. (2000). *Materials for an exploratory theory of the network society1.* The British Journal of Sociology, 51(1), 5-24.

CETIC (2023). TIC Domicílios 2022 - Coletiva de imprensa. Comitê Gestor da Internet no Brasil. São Paulo, 16 de maio de 2023.

CETIC (2024). TIC Domicílios 2023. https://cetic.br/pt/pesquisa/domicilios/indicadores/, 17 de março de 2024.

Choi, E., Kim, J., & Park, N. (2023). *An Analysis of the Demonstration of Five-Year-Long Creative ICT Education Based on a Hyper-Blended Practical Model in the Era of Intelligent Information Technologies.* Multidisciplinary Digital Publishing Institute, Applied Sciences, 13(17), 9718.

Cooper, M. (2010). *The Socio-economics of digital exclusion in America.* 38th Research Conference On Communications, Information And Internet Policy. TPRC, 1-43.

Correa, T., Valenzuela, S., & Pavez, I. (2022). *For better and for worse: A panel survey of how mobile-only and hybrid Internet use affects digital skills over time.* New Media & Society, 26(2), 995-1017

Costa, J. D., Santos, W. L., Silva, J. S., & Alves, M. M. S. (2019). Tecnologias e educacao: O uso das TIC como ferramentas essenciais para o processo de ensino e aprendizagem. *Brazilian Journal of Development*, *5*(11), 25034-25042. https://doi.org/10.34117/bjdv5n11-177

Cruz-Jesus, F., Vicente, M. R., Bacao, F., & Oliveira, T. (2016). The education-related digital divide: An analysis for the EU-28. Computers in Human Behavior, 56, 72–82. https://doi.org/10.1016/j.chb.2015.11.027

Damiani, M. F., Bielemann, R. M., Menezes, A. B., & Gonçalves, H. (2016). Afinal, o uso doméstico do computador esta associado à diminuição da reprovação escolar? Resultados de um estudo longitudinal. Fundação Cesgranrio, Ensaio: Avaliação e Políticas Públicas em Educação, 24(90), 59-81.

Di Pietro, G. (2021). Changes in Italy's education-related digital divide. Economic Affairs, 41(2), 252–270. https://doi.org/10.1111/ecaf.12471

Dutra, J. F., Firmino Júnior, J. B., & Fernandes, D. Y. S. (2023). Fatores que podem interferir no desempenho de estudantes no ENEM: uma revisão sistemática da literatura. Revista Brasileira de Informática na Educação, 31, 323-351.

Elena-Bucea, A., Cruz-Jesus, F., Oliveira, T.et al. (2021) Assessing the Role of Age, Education, Gender and Income on the Digital Divide: Evidence for the European Union. Inf Syst Front, 23, 1007–1021. https://doi.org/10.1007/s10796-020-10012-9

Engelbrecht, J., Llinares, S., & Borba, M.C. (2020). *Transformation of the mathematics classroom with the internet.* ZDM Mathematics Education, 52(5), 825–841.

Faith, B., & Hernandez, K. (2024). Smartphone- and Tablet-Reliant Internet Users: Affordances and Digital Exclusion. Media and Communication, 12, 8173. https://doi.org/10.17645/mac.8173

Feijó, J. R., & França, J. M. S. (2021). *Diferencial de desempenho entre jovens das escolas públicas e privadas.* Estudos Econômicos, 51(2), 373–408.

Feijó, J. R., França, J. M. S., & Neto, V. R. P. (2022). Desempenho dos estudantes ao final do ensino médio: Mensurando a influência direta e indireta da educação dos pais. Revista Brasileira de Economia, 76(1), 30–56.

Filatro, A. (2022). Educação a distância e tecnologias aplicadas à educação. Série Universitaria, Editora Senac, São Paulo.

Gallardo, R. (2019). *Bringing Communities into the Digital Age.* State & Local Government Review, 51(4), 233–241.

Géron, A. (2017). *Hands-on Machine Learning with Scikit-Learn & TensorFlow (Second Edition*). O'Reilly Media. Sebastopol, CA, USA.

Gil Quintana, J., & Vida De León, E. (2022). Brecha Digital Versus Inclusión en Educación Primaria. Perspectiva de las Familias Españolas. REICE. Revista Iberoamericana sobre Calidad, Eficacia y Cambio en Educación, 20(2). https://doi.org/10.15366/reice2022.20.2.005

Goldhammer, F., Gniewosz, G., & Zylka, J. (2016). *ICT Engagement in Learning Environments. Assessing Contexts of Learning. Methodology of Educational Measurement and Assessment*. Springer, Cham.

Gottschaw, F., & Weise, C. (2023). Digital equity and inclusion in education: An overview of practice and policy in OECD countries (OECD Education Working Papers 299; OECD Education Working Papers, Vol. 299). https://doi.org/10.1787/7cb15030-en

Gu, J. (2021). Family Conditions and the Accessibility of Online Education: The Digital Divide and Mediating Factors. Sustainability, 13(15), 8590. https://doi.org/10.3390/su13158590

Hermida, J. F., & Bonfim, C. R. S. (2006). A educação a distância: história, concepções e perspectivas. Revista HISTEDBR On-line, n. especial, 166–181.

Hilbert, M. (2016). The bad news is that the digital access divide is here to stay: Domestically installed bandwidths among 172 countries for 1986-2014. *Telecommunications Policy*, 50, 567-581. https://doi.org/10.1016/j.telpol.2016.01.006

Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira – INEP (2024a). Página principal do ENEM. Disponível em https://www.gov.br/inep/pt-br/areas-de-atuacao/avaliacao-e-exames-educacionais/enem.

Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira – INEP (2024b) . Microdados ENEM. Disponível em: https://www.gov.br/inep/pt-br/acesso-a-informacao/dados-abertos/microdados/enem.

Izquierdo, J., & Paulo, M. de A. L. de . (2023). Inclusão digital e desempenho escolar no contexto da pandemia: uma análise comparativa entre Brasil e Colômbia. *Civitas: Revista De Ciências Sociais*, *23*(1), e42196. https://doi.org/10.15448/1984-7289.2023.1.42196

Jackson, L. A., von Eye, A., Biocca, F. A., Barbatsis, G., Zhao, Y., & Fitzgerald, H. E. (2006). *Does home internet use influence the academic performance of low-income children?*. Developmental psychology, 42(3), 429–435.

Kartiasih, F., Djalal Nachrowi, N., Wisana, I. D. G. K., & Handayani, D. (2023). Inequalities of Indonesia's regional digital development and its association with socioeconomic characteristics: A spatial and multivariate analysis. Information Technology for Development, 29(2–3), 299–328. https://doi.org/10.1080/02681102.2022.2110556

Koutroumpis, P. (2009). *The economic impact of broadband on growth: A simultaneous approach.* Telecommunications Policy, 33(9), 471–485.

Lasisi, M., & Ogunsina, O. A. (2025). Globalization and the Digital Divide. Em Encyclopedia of Libraries, Librarianship, and Information Science (p. 225–232). Elsevier. https://doi.org/10.1016/B978-0-323-95689-5.00248-0

Lei, J., & Zhou, J. (2012). *Digital Divide: How Do Home Internet Access and Parental Support Affect Student Outcomes? Education Sciences,* 2(1), 45-53.

Lima, M. F., & Araújo, J. F. S. (2021). A utilização das tecnologias de informação e comunicação como recurso didático-pedagógico no processo de ensino e aprendizagem. Revista Educação Pública, 21(23).

Méndez-Domínguez, P., Carbonero Muñoz, D., Raya Díez, E., & Castillo De Mesa, J. (2023). Digital inclusion for social inclusion. Case study on digital literacy. Frontiers in Communication, 8, 1191995. https://doi.org/10.3389/fcomm.2023.1191995

Monteiro, S. M. (2022). Um olhar sobre a prova de matemática do ENEM 2019 na perspectiva de gêneros. Dissertação, Centro de Ciências, Universidade Federal do Ceará, Fortaleza.

Moraes, C. P., Peres, R. T., Barbosa, M. T. S., & Pedreira, C. E. (2022). Equidade e desempenho no Exame Nacional do Ensino Médio: Um estudo sobre sexo e raça nos municípios brasileiros. Arquivos Analíticos de Políticas Educativas, 30(68), 1-21.

Morte-Nadal, T., & Esteban-Navarro, M. A. (2022). *Digital Competences for Improving Digital Inclusion in E-Government Services: A Mixed-Methods Systematic Review Protocol.* International Journal of Qualitative Methods, 21, 1-9.

Oliveira, R. P., & Araujo, G. C. (2005). Qualidade do ensino: uma nova dimensão da luta pelo direito à educação. Revista Brasileira de Educação, 28, 05-23.

Organização das Nações Unidas Brasil (2024). Os Objetivos de Desenvolvimento Sustentável no Brasil, Educação de qualidade. Disponível em: https://brasil.un.org/pt-br/sdgs/4.

Pagán, F. J. B., Martínez, J. L., & Máiquez, M. C. C. (2018). *Internet use by secondary school students: A digital divide in sustainable societies?* Sustainability, 10(10), 3703.

Prince Torres, Á. C. (2024). Derecho a la igualdad, brecha digital y COVID-19: Experiencia latinoamericana educativa en Secundaria para postpandemia. Foro Educacional, 42, 83–110. https://doi.org/10.29344/07180772.42.3693

Puspitasari, L., & Ishii, K. (2016). Digital divides and mobile Internet in Indonesia: Impact of smartphones. Telematics and Informatics, 33(2), 472–483. https://doi.org/10.1016/j.tele.2015.11.001

Rajam, V., Reddy, A. B., & Banerjee, S. (2021). Explaining caste-based digital divide in India. Telematics and Informatics, 65, 101719. https://doi.org/10.1016/j.tele.2021.101719

Reed, P., & Reay, E. (2015). *Relationship between levels of problematic Internet usage and motivation to study in university students.* Higher Education, 70(4), 711–723.

Sant'ana, D. A., Pache, M. C. B., Borges, P. P., & Dias, J. L. E. (2021). *Accessibility and digital inclusion in Brazil and South Korea: A comparison between micro and macro territorial approach.* Sustainable Cities and Society, 64, 102524.

Sujarwoto, S., & Tampubolon, G. (2016). *Spatial inequality and the Internet divide in Indonesia 2010–2012.* Telecommunications Policy, 40(7), 602–616.

Sutiah, S., Slamet, S., Shafqat, A., Supriyono, S. (2020). *Implementation of distance learning during the covid-19 pandemic in faculty of education and teacher training.* Cypriot Journal of Educational Sciences, 15(5), 1204–1214.

UNESCO (2024), Incheon Declaration: *Education 2030: Towards Inclusive and Equitable Quality Education and Lifelong Learning for All,* Conference: World Education Forum, Incheon, Korea R, 2015.

Van Deursen, A. J. A. M., & Van Dijk, J. A. G. M. (2015). Toward a Multifaceted Model of Internet Access for Understanding Digital Divides: An Empirical Investigation. The Information Society, 31(5), 379–391. https://doi.org/10.1080/01972243.2015.1069770

Vimalkumar, M., Singh, J. B., & Sharma, S. K. (2021). Exploring the multi-level digital divide in mobile phone adoption: A comparison of developing nations. Information Systems Frontiers, 23(4), 1057–1076. https://doi.org/10.1007/s10796-020-10032-5

Wang, C., & Si, L. (2024). The Intersection of Public Policy and Public Access: Digital Inclusion, Digital Literacy Education, and Libraries. Sustainability, 16(5), 1878. https://doi.org/10.3390/su16051878

Warschauer, M. (2003). *Technology and social inclusion: rethinking the digital divide.* Cambridge, Massachusetts, The MIT Press.

Yu, X., & Liu, S. (2022). *Disparities in Online Use Behaviours and Chinese Digital Inclusion: A 10-Year Comparison.* International Journal of Environmental Research and Public Health, 19(19), 11937.

Submitted: 05/21/2025
Preprint: 05/19/2025
Approved: 07/01/2025
Section Editor: Suzana dos Santos Gomes

ACKNOWLEDGMENT
This research had the support of Fundação Instituto de Administração (FIA).

DATA AVAILABILITY DECLARATION
The content will be available at the time of the article's publication.

AUTHOR’S CONTRIBUTIONS
Author 1 – Data collection, data analysis, and writing of the text.
Author 2 – Research advisor, actively participated in research conceptualization, literature review, and text revision.
Author 3 – Actively participated in research conceptualization and text revision.

DECLARATION OF CONFLICT OF INTEREST
The authors declare that there is no conflict of interest in this article.