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The Impact of Internet and Computers on Young Minds: Evidence from Rural Brazilian Schools

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Abstract

This paper presents the preliminary results of a field experiment in which we tested how second to fifth graders respond to the use of computers with satellite internet connection at school. We collect data from one treated school, that received the new, self-sustained computer lab, and two controls - randomly selected from a group of rural school with similar characteristics. About half of the 310 participant students report not having used a computer before the intervention. We find that the computer lab increases the general preference for attending school and their engagement to asking questions and doing homework. This positive change in attitudes seems to explain why students in the treated school register a 15 percentage point increase in correct answers in language tests, while the effect is insignificant for math grades. Yet, these average treatment effects mask substantial heterogeneity between children. Among those who have not used a computer before the improvement in both math and language classes are strong and significant. Finally, the intervention helped develop computer skills for studying for exams and recreational activities.

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1 Introduction

Estimating the effects of computer introduction in schools has produced mixed results since the seminal study by Angrist and Lavy (2002). In theory, the access to technology is an environmental factor that may facilitate the improvement of children's cognitive skills and abilities (Cunha and Heckman 2007). However, the overall effect of technology-based instruction depends on whether it generates higher or lower returns than traditional instruction methods (Bulman and Fairlie 2016). This raises the question: why do so many computer and laptop donation programs fail to deliver the anticipated benefits? Are students effectively learning to use technology without direct instruction? Additionally, how do students' attitudes toward learning influence their interactions with computers?

A closer look at the details in subsequent studies revealed that teacher behavior crucially impacts the effectiveness of computer use to enhance student grades. The qualitative survey of the One Laptop per Student Program in Brazil by Andriola and Gomes (2017) for example highlights that its successful implementation suffers from recurrent difficulties in continuous teacher training. Barrera-Osorio and Linden (2009) find that, even though training had been provided, teachers may still fail to apply the technology adequately in their classes. Thus, a variety of studies indicate that in many unsuccessful cases either teachers lack motivation to use technology in their classes or are restricted by their proper digital abilities and knowledge in the subject they are teaching (Hill, Rowan and Ball 2005; Nogueira et al. 2022). Another threat to better school performance comes from the internet use itself. Belo, Ferreira and Telang (2014), for example, find that broadband internet adoption can have a negative effect when it deviates attention towards unproductive media content. Among schools that block certain popular sites, they observed that performance was relatively better.

More encouraging results are found regarding the development of computer skills. At least among children in middle- or high-school the literature seems to converge towards the conclusion that computer use stimulates digital and cognitive skills (Cristia et al. 2017; Fairlie 2012). Another aspect that generally produced positive outcomes is the use of educational games. The meta-analyses by Lei et al. (2022) and Yıldırım and Şen (2021) indicate that many experimental studies from a variety of countries find positive effects of gamification on student performance, independent of whether the courses are technology-based or not.

Finally, there is a robust collection of empirical evidence demonstrating that students' positive attitudes towards Information and Communication Technology (ICT) are significantly correlated with improved performance in mathematics and science (Courtney et al. 2022; Petko, Cantieni and Prasse 2017; Tourón et al. 2019). These three examples stem from the PISA survey, as does most of the literature on this topic and thus is of non-experimental nature. Two notable recent exceptions that use a RCT as in the present case found that attitudes towards learning is indeed detrimental for the success of an ICT program, though the context of these studies differs from the present one. Higuchi, Sasaki and Nakamuro (2020) study how Skype can enhance English communications skills and Cardim, Molina-Millán and Vicente (2023) on the effects of a Computer-assisted Learning software in Angola.

This paper reports findings from the ongoing *Educa.Conecta Learning* program, implemented in early 2023. In the course of the program, a self-sustained computer lab with internet via satellite was installed in a rural school in Brazil and teachers were given targeted pedagogical training and technical assistance. Teachers were introduced to educational games before the start of the program but no binding restrictions were given regarding the methodology in the computer classes. The intervention is designed as a clustered randomized controlled trial with about 310 students over a two-year period.

Given that the present setting addresses several of the aforementioned issues previous studies identified, we expect a strictly positive impact on student performance. Another objective of this research is to evaluate whether the intervention had an effect on students' attitudes. To this end, we applied standardized exams evaluating abilities in math and Portuguese language. Furthermore, we test whether the intervention affected students' computer skills and attitudes towards learning and technology using a designed questionnaire applied by a trained team in both the treated and control schools.

We find a substantial improvement in language test scores at the treated school, with a significant 15-percentage point increase in Portuguese exam results due to the computer lab intervention. Additionally, it significantly enhanced students' engagement in school and their computer skills, emphasizing the importance of digital literacy for future career success and the development of academic abilities. We also find that the positive effects on the overall mean are driven by the students who do not have previous computer experience. This pilot design of a public policy thus shows how the provision of technology in schools helps overcome the digital divide for socioeconomically marginalized populations, with the double dividend of increasing their academic performance. A detailed discussion about how our results complement the existing literature is provided in a separate section before the conclusion of the paper.

The rest of the paper is organized as follows. Section 2 explains the methodological aspects of the intervention, the selection of participant schools and our econometric estimations. Section 3 presents the preliminary findings. Section 4 discusses our results and contribution in the light of the previous papers. Section 5 concludes and offers policy recommendations.

2 Methodology

2.1 Sample selection

The first step in the implementation of the field experiment was the random selection of one school to receive the computer lab (treatment) and two highly comparable schools to be used as control units. The three participants were part of a pool of candidate schools. Those candidates were chosen on the basis of objective criteria extracted from data disclosed by the National Institute of Educational Studies and Research (INEP) as explained in the following.

Initially, we restrict the target group such that potential participant schools fulfill the following criteria: the elementary schools are rural, public, under state administration, and located in the Federal District. These restrictions already reduce the number of candidate school from 1,491 to only 83 which is not surprising given that the Federal District (DF) is by far the smallest and youngest of the 27 federative units in Brazil. Furthermore, the target schools need to have a minimum infrastructure in terms of regular drinking water supply, public electricity supply, and have sanitary sewage, so that these external factors do not negatively affect classes. The remaining 24 target schools neither have a computer laboratory nor internet access before our intervention. Finally, we eliminate schools that stand out by expressive above or below average values in terms of students' performance and socioeconomic level. 7 highly comparable rural elementary schools in the DF remain in the last subset of similar schools. Among these 7 schools, the allocation of receiving treatment (1 school) and being part of the control group (2 schools) was random. No selection is made regarding individuals, i.e., all students in the each of the three participant schools are attended equally. The design of the present study can thus be classified as a clustered two-level random controlled trial (RCT).

Note that the study was not pre-registered publicly in one of the common research institutions and these results should be considered as exploratory. However, the design of the study was carefully planed, a literature review was conducted, and hypothesis were formulated before the beginning of the intervention because the project proposal was submitted to a local research funding institution, the FAP-DF. The approval of the funding was published on 3. January 2023 on page 39 in the Official Gazette of the Federal District.

Table 1 presents average values of four sets of variables in the three schools under consideration in the pre-treatment period to check whether the participants are comparable ex ante. Panel A and B show that the socio-demographic and household characteristics of students in the treated school are highly similar to those of the two control units. There is a roughly equal number of boys and girls in the sample, 60% to 70% of them live with both parents and have, on average, 2.5 siblings. Virtually all of the households are equipped with electric energy, a cell phone, and internet access but only less than 50% have a computer.

Panels C and D in table 1 refer to students' school preferences and computer experience, variables that will be used as outcomes in our econometric analysis. Again, we observe that statistical differences in average values between the treated and control schools are rejected in most of the cases. The exception is that students in the treated school seems less enthusiastic about math lessons and school itself, compared to their peers in control school number 2. Yet, about 50% of participants in the three school have previously used a computer, which is much in line with the share of households with such a device. Among those who use computers, the proficiency of typing, searching, playing, and studying is also highly similar in treated and control schools.

The number of observations between schools is still considerably different in table 1 but it is rather small compared to the original sample mean and standard deviation of 796 and 929, respectively, among public schools in the Federal District. The remaining differences in the number of students stems from the fact that the smallest control school with 63 observations per wave had only one parallel class available for all the grades from 2nd to 5th grade, the largest school had two parallel classes. Still, the number of students per class are comparable in relation to the discrepancies in the sample of schools within the same state.

2.2 Intervention

The intervention of the present field experiment is the implementation of a self-sustained computer lab with satellite internet access and solar energy. The selected rural school

Table 1: Pre-treatment mean differences across schools

	(1) Treat.	(2) Obs.	(3) Ctrl. 1	(4) Obs.	(5) Ctrl. 2	(6) Obs.	(7) Diff. 1	(8) Diff. 2
Panel A: Socio-demographic characteristics								
boys	0.533	92	0.524	63	0.484	155	0.009	0.049
white	0.337	92	0.349	63	0.342	155	-0.012	-0.005
parents	0.728	92	0.603	63	0.690	155	0.125	0.038
siblings	2.554	92	2.397	63	2.600	155	0.158	-0.046
school bus	0.957	92	0.937	63	0.897	155	0.020	0.060*
Panel B: Household characteristics								
electricity	1.000	92	1.000	63	0.994	155	0.000	0.006
computer	0.478	92	0.365	63	0.445	155	0.113	0.033
cell phone	1.000	92	1.000	63	0.994	155	0.000	0.006
internet	0.967	92	0.968	63	0.942	155	-0.001	0.025
Panel C: School preference								
school	3.196	92	3.286	63	3.355	155	-0.090	-0.159*
math	3.130	92	2.952	62	3.310	155	0.179	-0.179*
Portuguese	2.879	91	2.758	62	2.719	153	0.121	0.160
question	1.615	91	1.905	63	1.748	155	-0.289	-0.133
homework	3.087	92	3.016	63	2.923	155	0.071	0.164
Panel D: Computer experience								
used	0.522	92	0.460	63	0.542	155	0.061	-0.020
open apps	0.521	48	0.778	27	0.509	110	-0.257**	0.012
type	2.422	45	2.519	27	2.365	96	-0.096	0.058
search	2.568	44	2.696	23	2.500	94	-0.127	0.068
play	2.513	39	2.852	27	2.705	95	-0.339	-0.192
study	2.125	24	2.727	11	2.310	71	-0.602	-0.185

Notes: The table reports mean values and the respective number of observations for selected variables in the treated and control schools 1 (EC Monjolo) and 2 (EC Sobradinho dos Melos). The last two columns report the p-values of two sample t-tests for mean equality between the treated and the two control schools, respectively, where standard errors in parenthesis are clustered at the school-level and * denotes significance at ten, ** at five and *** at one percent level. The selected variables are defined as follows: *boys:* share of male students; *white:* share of students with white skin color; *parents:* share living together with both parents; *school bus:* share that usually come to school by bus; *energy, computer, cell phone, and internet:* share of students that report to have these amenities in their household; *school, math, Portuguese:* preference for school (in general), math, and Portuguese lessons, measured on a five-point Likert scale from 0 (hate) to 4 (love); *question, homework:* frequency of asking questions in class and doing homework measured on a five-point Likert scale from 0 (never) to 4 (everyday); *used, open apps:* share of students that already used a computer and report to know how to open applications; *type, search, play, and study:* proficiency of knowing how to type, search, play, and study using a computer measured on a five-point Likert scale from 0 (very bad) to 4 (very good).

also received the necessary technical assistance and training for their teachers and staff without having to spend its own scarce financial resources.

The computer lab was arranged in a previously spare 43 m^2 room and features 15 personal desktop computers with wide tables to accommodate 2 to 3 students in front of each computer, if necessary. The teacher has a proper equipment on his desk, a screen with projector, and a central management unit for the entire system. The teacher is thus able to control and monitor students' activities during the classes.

Due to the frequent power outages and blackouts that occur regularly in rural areas, we implemented a photovoltaic energy capture system on the roof of the computer lab to ensure uninterrupted operation. The most potent satellite option from the provider *Starlink* supplies internet to the all computers. To protect students from accessing inappropriate content and to ensure their activities in the lab remain focused on educational exercises, we installed a paid software that blocks any content unsuitable for individuals under 16.

Teacher training was divided into technical and pedagogical sessions of 6 and 12 hours, respectively. The technical part covered theoretical and practical components, followed by individual and team assessments. The workshops focused on familiarizing teachers with the technical operations of the machines, preparing them for subsequent workshops and teaching. Technical support had been provided over the entire intervention period such that upcoming problems could be solved in a timely manner. The pedagogical parts were led by an experienced professional covering theoretical aspects and practical components including educational tools, sites, and games. We expect these workshops to empower the teachers to independently choose and experiment which tools are most adequate for their students.

2.3 Estimation

In line with the clustered RCT design of the present intervention, we use the classification of school into treatment and control groups and apply difference-in-difference (DiD) regressions to estimate the impact of the computer lab on students.

We collected the necessary data by applying a designed questionnaire as well as standardized tests before and after the installation of the computer lab. The complete questionnaire is available upon request but the relevant questions used here can be directly inferred from the description of the variables we extract from it. Since we target young children, we hired a team of qualified interviewers to ask the questions, register and, finally, digitize the answers. The questions are short, straightforward, and as simple as possible to avoid comprehension difficulties. The exams are grade-specific and aligned with standardized tests applied regularly by a public organ in another federal state. They contain six questions in each of the subjects math and Portuguese language. Teachers then applied our tests as a preparation for students' usual exams.

Our DiD regressions take the following form

$$outcome_{icst} = \alpha + \beta Post_t \times Treat_s + \gamma Treat_m + \delta Post_t + \psi X_{it} + \epsilon_{icst} \qquad (1)$$

where i represents a student from class c in school s at time t. $Post_t$ is an indicator variable for the second, post-intervention period. $Treat_s$ is treatment indicator and thus assumes value 1 for the school with the computer lab and 0 otherwise. The coefficient β of the interaction term between $Treat_s$ and $Post_t$ measures the average effect of the intervention that is the "intention-to-treat" (ITT).[1] Standard errors are clustered at the school-level in all regressions.

We use three sets of outcome variables. (1) The share of correct answers in the math and Portuguese language exam. (2) Students' attitudes towards school and learning were

[1] Because of (slightly) imperfect compliance due to students' school exit and entry, the full effect of the intervention needs to be derived from an instrumental variable correction (Cristia et al. 2017). In the present case this local average treatment effect (LATE) cannot be estimated because students are not followed once they move to another school.

derived from our questionnaires. Participants in the three schools were asked about how much they liked school, math classes, Portuguese classes, as well as about the frequency of questioning during classes, and doing homework, measured on five-point Likert scales. (3) Six outcome variables regarding computer use and skills were also derived from the questionnaires, including whether students are able to open programs, type on the keyboard, search the internet, know how to play, and use the computer for studying. Given that some variables were unbalanced between treatment and control schools and because of the small sample size, we report results with and without the household and socio-demographic control variables X_{it} reported in panels A and B of table 1.

3 Results

Table 2 reports the results from questions regarding students' attitudes towards school and learning. Each of the columns refers to an OLS regression with a different outcome variable, following equation (1). The coefficients of the interaction term *treat* × *post* estimate the impact of the computer lab installation on students' attitudes toward school and learning in treated schools, relative to those in control schools.

Table 2: Students' attitudes towards school and learning

	(1)	(2)	(3)	(4)	(5)
dep. var.:	school	math	port.	question	homework
		Panel A: no control variables			
treat × post	0.207***	-0.094	0.078*	0.297**	0.149**
	(0.014)	(0.079)	(0.018)	(0.048)	(0.022)
Observations	607	606	601	605	607
R^2	0.006	0.013	0.010	0.016	0.017
		Panel B: including personal control variables			
treat × post	0.215**	-0.109	0.081*	0.308**	0.150**
	(0.022)	(0.076)	(0.021)	(0.055)	(0.018)
Observations	607	606	601	605	607
R^2	0.022	0.067	0.026	0.031	0.054

Notes: The table reports coefficients from OLS regression according to eq. (1). The dependent variable *school, math, port* represent: preference for school (in general), math, and Portuguese lessons, respectively, measured on a five-point Likert scale from 0 (hate) to 4 (love); *question, homework* represent: frequency of asking questions in class and doing homework, respectively, measured on a five-point Likert scale from 0 (never) to 4 (everyday). Panel A estimates a model without any control variables. Panel B introduces individual-level controls, including family and household structure, race, gender, and school transport mode. Standard errors, reported in parentheses, are clustered at the school level. Statistical significance is denoted as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Overall, comparing panels A and B of table 2 reveals that including students' household and socio-economic control variables has little effect on the estimated coefficients. The results in column (1) indicate that the treated students show a higher preference for going to school. The size of the effect corresponds to a fifth of a difference between two consecutive units of the 5-point Likert scale, which is reasonable but not huge. This positive effect is statistically significant, below the 1% level. The computer lab also seems to slightly increase students' preference towards Portuguese classes but not towards math. It thus seems that the higher valuation towards school overall is related to the computer lab, but this positive effects does not (yet) spill over to their traditional math and language classes outside the lab.

Encouraging effects are again registered in columns (4) and (5). The computer lab seems to stimulate students' interactions with their teachers in terms of asking more questions and being more engaged. Moreover, we observe that the frequency of doing homework is positively affected though the lessons in the computer lab. Both of the latter 'intention to treat' coefficients are highly significant.

The first column in Panel A of table 3 stems from the question whether the student has ever used a computer. Although, after the intervention all students in the treated school should have had contact with a personal computer, the magnitude of the estimated coefficient is striking. It indicates an increase by 36% percentage points. This size is plausible given that only half of the second to fifth grade students in our sample have not used a computer at the moment we conducted the first interview. It is also interesting to note that the coefficient of the *post* variable (omitted from the table) is equal to 0.08 and highly significant. Hence, over the 5-month period between the first and the second application of the questionnaire, students' exposure to computer use increases in both the treated and control schools. Both changes sum up to an increase of 44% in the treated school, indicating that in fact close to 100% of students have used a computer once the lab was available to them.

The dependent variables in columns (2) to (6) refer to specific computer skills. The sample in these estimations is conditional on having used a computer already before the intervention began. Without this restriction it would be obvious that the estimations indicate higher skills because a large part of students had not used a computer before the provision of the computer lab. The estimations in table 3 thus compare the skills among computer users. In both panels A and B, we register significant positive development in skills required to open applications, play games, and use the computer to study for exams. Still, the computer lab only contributes little or no significant impact on typing on the keyboard and searching on the internet.

Regarding academic performance, our preliminary results provide the short-term effects of the intervention on students' performance in mathematics and Portuguese language tests. The estimation results are reported in table 4. Columns (1) and (2), respectively, present the treatment effects on the proportion of accurate responses in mathematics and Portuguese. Our findings indicate that the intervention is correlated with a statistically significant increase (less than 1 percent) solely in performance on Portuguese tests. The coefficient of interest ($treat \times post$) is estimated at 0.15 in column (2), with a standard error of 0.012. This indicates that the treated school exhibits a 15 percentage point increase in correct answers in language tests. As we have seen before, the results are highly similar independent of whether we control for the student-level variables.

The absence of a significant effect on mathematics performance may be attributed to the low proportion of students expressing a preference for mathematics, as evidenced in table 2. This result suggests an opportunity to promote the effective utilization of applications and computers to enhance students' engagement with the discipline. To better understand

Table 3: Students' computer use and abilities

	(1)	(2)	(3)	(4)	(5)	(6)
dep. var.:	used	open apps	type	search	play	study
			Panel A: no personal control variables			
treat × post	0.362***	0.213*	-0.030	0.026*	0.233**	0.248**
	(0.002)	(0.057)	(0.043)	(0.007)	(0.030)	(0.026)
Observations	602	361	332	337	333	206
R^2	0.090	0.049	0.026	0.001	0.012	0.034
			Panel B: including personal control variables			
treat × post	0.352***	0.247**	-0.036	0.084	0.253**	0.256**
	(0.006)	(0.045)	(0.032)	(0.053)	(0.032)	(0.026)
Observations	602	361	332	337	333	206
R^2	0.255	0.080	0.044	0.018	0.022	0.075

Notes: The table reports coefficients from OLS regression according to eq. (1). The dependent variables *used, open apps* represent: share of students that already used a computer and report to know how to open applications, respectively; *type, search, play, and study* represent proficiency of knowing how to type, search, play, and study using a computer, respectively, measured on a five-point Likert scale from 0 (very bad) to 4 (very good). The responses in conditional on having experience with a computer. Panel A estimates a model without any control variables. Panel B introduces individual-level controls, including family and household structure, race, gender, and school transport mode. Standard errors, reported in parentheses, are clustered at the school level. Statistical significance is denoted as follows: $^*p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

this zero result, we perform a refined analysis for subgroups of students using additional interaction terms in the standard DiD in equation (1).

Finally, columns (3) and (4) of Table 4 examine whether prior experience with computers moderates the effect of the intervention on students' academic performance. In fact, the effect of the program appears to be primarily driven by students with limited prior exposure to technology. The treatment effect on students *without* prior computer experience is positive and highly significant for both mathematics and Portuguese. For Portuguese the increase in correct answers due to the experience in the computer lab effect is as high as 25 percentage points for those without computer experience and drops to 7.6 percentage points for students with prior computer experience. This finding is particularly relevant given the socioeconomic context of the rural schools analyzed and the objective of our intervention to strengthen teacher-student interactions through technology integration in the educational process. Moreover, the results remain robust even after controlling for individual characteristics, as shown by the comparison between Panel A and Panel B, further reinforcing the validity of our findings.

4 Discussion

Student grades in standardized exams exhibit significant variation both across different countries and within individual countries, influenced by a number of factors including socio-economic status, educational resources, and cultural heritage (Ehrl and Alves

Table 4: Students' exam grades

	(1) Math	(2) Port.	(3) Math	(4) Port.
	Panel A: no personal control variables			
treat × post	0.078	0.153***	0.088**	0.248***
	(0.036)	(0.012)	(0.011)	(0.014)
treat × post × Comp. Exp.			-0.027	-0.173***
			(0.046)	(0.007)
Observations	587	586	579	579
R^2	0.007	0.297	0.039	0.305
	Panel B: including personal control variables			
treat × post	0.075	0.154***	0.089**	0.249***
	(0.036)	(0.011)	(0.010)	(0.014)
treat × post × Comp. Exp.			-0.028	-0.173***
			(0.047)	(0.006)
Observations	579	579	579	579
R^2	0.028	0.314	0.056	0.322

Notes: The table presents coefficients from an Ordinary Least Squares (OLS) regression, as described in equation eq. (1), for the scores achieved in standardized tests. The dependent variables are the ratios of positive responses in assessments for both mathematics and the Portuguese language. The variable *Comp. Exp* is a dummy that equals 1 if the student had any prior experience with computers before the treatment and 0 otherwise. Panel A estimates a model without any control variables. Panel B introduces individual-level controls, including family and household structure, race, gender, and school transport mode. Standard errors, reported in parentheses, are clustered at the school level. Statistical significance is denoted as follows: $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

2024). This paper presents evidence on strategies to bridge the school performance gap even within narrowly defined regions and rural contexts. Our findings are particularly encouraging because Brazil is known for its high and persistent regional inequalities regarding income, education, skills, and access to internet and technology (de Almeida, Ehrl and Moreira 2021; Ehrl and Monasterio 2019; Silva et al. 2020)

A first remarkable point is related to how much time the utilization of the computer lab needs to provoke a measurable impact. Some studies have questioned whether a one-year observation period is sufficient to capture the effects of a computer infrastructure invention (Angrist and Lavy 2002; Lakdawala, Nakasone and Kho 2023). In our case, a six-month period after the inauguration of the computer lab has shown to be sufficient to achieve a positive transformation of attitudes, grades, and skills. The quickness of transformation may be related to the fact that the students were excited about the new opportunity and they had enough time to use the new facility given that they are fairly young and a majority of them had not used a computer before. The organization of the full-time schedule with 50% lessons and the other 50% filled with extra-curricular activities, among others in the computer lab, may have accelerated the transformation speed. Since the use of the computer lab is thought to be permanent and further tests and questionnaires will be applied within the scope of this research project, we are optimistic to observe further positive changes.

Experimental studies found mixed results on the effects of ICT provision programs on educational outcomes. The predominantly positive effects of the present intervention may be manifest because its design was intended to avoid hurdles identified by previous research. First, the integration of the computer lab into the full-time schedule of students did not come at the expense of traditional lessons, as alerted by Cristia et al. (2017), Leuven et al. (2007), or Angrist and Lavy (2002) and it was well-managed (Bai et al. 2016). Second, the marginal returns to computer are supposed to be higher in rural parts of a developing country as compared to programs in developed countries where most of the children have access to a computer at home, too. Third, the potential barrier of lacking teacher adoption to the computer lab (Barrera-Osorio and Linden 2009; Bulman and Fairlie 2016) was anticipated and addressed through recurrent workshops and technological training.

The literature seems to have reached a consensus that ICT investments, particularly paired with rapid internet access, leads to improved computer skills, independent of whether the technology is used at school or at home, see Malamud and Pop-Eleches (2011), Malamud et al. (2019), Falck, Mang and Woessmann (2018) Okyere (2022), or the review by Rodriguez-Segura (2022). Our observations on gaining computer skills are thus in line with the previous evidence. However, Fuchs and Woessmann (2004) question whether computer skills generate any relevant direct returns in the labor market compared to basic academic skills.

The relation between computer use and attitudes towards learning at school is the least explored aspect in the previous literature. To the best of our knowledge, there is only one comparable paper that evaluates the impact of an ICT investment on preferences towards learning in school in an RCT setting. Cardim, Molina-Millán and Vicente (2023) explore the effects of a computer assisted learning software on students' and teachers' attitudes towards school. A common point is that the authors also observe higher dedication towards math classes, but not towards reading or school per se. The Angolan students also attend classes more frequently, an aspect we could not observe in our setting. Despite these similarities, the authors do not observe significant increases in math and reading grades but only in science. In line with the present results, positive effects are found regarding students' independence and self-efficiency in learning (DeBoer et al. 2019) or on attitudes towards computer-assisted language learning (Rahimi et al. 2011).

The final point to discuss concerns the heterogeneous effects of treatment by previous computer experience. We observed that the using computers at school particularly helps the disadvantages group of students who did not have access to a computer before. This finding thus suggests that providing access to technology can mitigate performance disparities linked to socioeconomic factors, highlighting the importance of equitable access to educational resources.

5 Conclusion

In this pilot study, we document the short-run effects of implementing a computer laboratory with internet connectivity on students' school performance, attitudes towards learning, and computer skills. Our findings reveal a significant improvement in the performance of students in language tests, while the average treatment effect is insignificant for math grades. The magnitude of our estimations suggests that the intervention increased the students' performance on Portuguese language exams by approximately 15 percentage points.

Additionally, we analyze students' attitudes toward school and learning. Understanding these attitudes is crucial for evaluating the effect of our intervention and identifying potential areas for improvement. We found that the computer lab increased the general preference for attending school and helped develop computer skills for studying and playing. These findings hold significance due to their implication in the cultivation of digital literacy skills among students, which are imperative for achieving success in the contemporary professional environment. The utilization of computers for academic purposes facilitates the acquisition of skills such as information literacy, mastery of digital communication, and proficiency in employing productivity tools.

As the experiment is ongoing, it is important to emphasize that the results should be interpreted with caution. Throughout the course of the research, two additional questionnaires and exams will be collected from the participants. Thus far respondent rates and participation are extraordinarily high so that attrition and sample selection do not pose major threats to identification of treatment effects. Future evaluations should also delve into the role teachers and on how their skill development potentialized students' outcomes. Another important limitation stems from the nature our clustered RCT design at the school-level where, due to the experimental nature of the study, the number of participant schools and students is limited. However, because of the previous selection of highly similar schools we are convinced that the parallel trends assumption holds and that schools are not exposed to different shocks over the short span of time.

Ethics and consent statement

We conducted this research in strict compliance with the ethical principles applicable to research involving human beings. We planned and executed all stages of the study with the commitment to guarantee the safety, privacy and well-being of the participants. To collect data, we administered questionnaires to students, ensuring that participation was voluntary and based on informed consent. Since the students were minors, we prepared a specific form for parents or guardians, in which we requested authorization for their children to participate. With this measure, we ensured respect for the rights of the participants and full transparency regarding the objectives and implications of the study. To avoid risks of stigmatization or discrimination, we adopted strict confidentiality measures, such as anonymizing data and using respectful language. In addition, we provided appropriate support to the participants whenever necessary. The study did not involve invasive or potentially harmful procedures, and all interactions took place in safe and controlled environments. We maintained the integrity of the research through strict data protection protocols and our commitment to transparency and anonymity. In this way, we conducted the study responsibly and in accordance with ethical principles, ensuring the respect and protection of all those involved in each phase of the investigation.

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