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DIGITAL TOOLS IN THE CLASSROOM: EVIDENCE FROM A LARGE-SCALE NATURAL EXPERIMENT

Ghazala Azmat, Denis Fougère, and Clémence Lobut

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Digital Tools in the Classroom: Evidence from a Large-Scale Natural Experiment*

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Abstract

We study the impact of the French ‘Digital Plan,’ a large-scale educational information and communication technologies (ICT) program that provides middle school students with access to mobile digital devices (i.e., either individual or shared access tablets), on students’ skills. Employing conditional random assignment and comprehensive administrative and survey data spanning several years, we establish a causal link between ICT access in the classroom and students’ academic, digital, and sociocognitive skills. On average, we find large positive treatment effects on academic and digital skills and collaborative capabilities but a negative effect on creativity. However, substantial variation in treatment effectiveness suggests important complementarities and substitutability of these tools given student, school or instructor characteristics. Tracking students into high school, we identify the lasting impact of treatment on performance in national exams and college-relevant choices, especially within STEM disciplines.

JEL Classification: I21, I28, J13, H53

Keywords: mobile digital devices; student skills; natural experiment

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1 Introduction

Training future citizens in the use of information and communication technologies (ICTs), such as personal internet-connected devices, is indisputably crucial in today's society. Digital technology is increasingly becoming an important part of modern learning in schools, as ICT is a pedagogical tool facilitating potential improvement in students' achievement and transformation of their schooling environment.¹ Across countries, there have been large investments to equip schools with ICTs. For example, even before the pandemic, the U.S. federal government, states, and school districts together spent as much as \$41 billion annually on educational technology on the development of digital uses and digital transformation.² However, despite the growing interest and research on this topic, there is little consensus on the effect of ICT use on students' skills.

The integration of digital tools into the classroom is undeniably important from an economic standpoint. However, there is considerable uncertainty regarding its actual effectiveness. The growing use of information and communication technology (ICT) in educational settings can enhance digital knowledge and skills, providing essential resources for the modern labor market that align with future demands. Engagement with digital tools in the classroom enables changes in pedagogical practices so that learning may be impacted in a broader sense, and the overall production function of learning may improve with technological advancements in education. A shift in traditional learning is likely to change the interactions between students and instructors. While digital tools may help facilitate communication between educators and students, advancements in educational software might also serve as a viable substitute for parental or teacher supervision. However, the introduction of digital learning is likely not without unintended consequences or potential drawbacks. Devices may create unnecessary distractions in the classroom, thus hampering the learning process. Likewise, incorporating modern tools might influence the social landscape in ways that are not obviously positive, such as the ways in which peers collaborate or communicate with one another.

Addressing the fundamental question of whether increased access to digital tools is potentially beneficial or detrimental to student learning is crucial. However, it is equally important to understand their optimal deployment in an educational environment. While proponents argue that the digital revolution can act as a 'great equalizer,' providing unprecedented access to information and resources, the heterogeneity in the ways these tools are integrated

¹In 2022, 85.5% 15-year-old students used a digital device for learning activities at school (OECD, 2015, Students

²US Department of Education, <https://tech.ed.gov/netp/digital-access-divide/>

into classroom learning creates concern that the expanded use of digital tools may exacerbate the already sizable learning inequalities across students and schools. The extent of integration (i.e., partially or fully) within the classroom is therefore relevant, as is the compatibility of tools with the user.

There are several empirical challenges when assessing the impact of ICT on learning. The adoption of digital tools is influenced by multiple factors, such as the learning environment, leading to standard endogeneity problems. The impact of these tools is also likely to be heterogeneous across multiple dimensions. For example, there may be interactions with student characteristics, such as gender and socioeconomic background, suggesting the differential effectiveness of these tools across individuals. Similarly, instructors' digital skills or characteristics may affect the efficacy of these tools. It is also important to assess the impact of ICTs across multiple outcomes, both in the short run and the long run. Addressing these issues requires random variation in the assignment of different forms of ICTs on a representative and sufficiently large sample that allows for robust estimates of the interactions and heterogeneous effects of ICT use.

In this paper, we use a natural experiment in which schools are randomly allocated into a large-scale (French) digital educational program to offer comprehensive insight into the impact of digital technology on students' learning and skills. Launched in 2015 by the French Ministry of Education, the Plan Numérique (or 'Digital Plan') aimed to increase technological access in schools through the provision of mobile digital equipment (i.e., tablets) to students in Grade 7 (i.e., the second year of middle school, aged 12-13 years old) until the end of middle school. We measure the impact of two randomly assigned different types of treatment (i.e., either individual or shared access tablets). At the end of each year, we explore the impact on a number of students' skill dimensions, including their digital, academic and sociocognitive skills. By tracking students after they finish middle school and enter high school, we study the lasting impact of treatment (until Grade 11) on their academic performance, as well as their college-relevant track and course choices.

The scale and representativeness of the program allow us to measure the heterogeneous impact of ICT access, its interactions with student and school characteristics and how it complements or replaces teacher skills. We analyze the impact (by treatment type) in terms of student characteristics (gender and social background) and teacher characteristics (gender, age, teaching contract, digital skills). Similarly, we measure the impact on 'priority education' versus 'nonpriority education' schools, where priority education schools are schools in less affluent areas that receive additional resources, allowing us to distinguish between the

school effect and the individual socioeconomic status effect across all schools.³

For three consecutive years, from 2015 to 2017, an open call was issued by the French Ministry of Education to middle schools in France, inviting them to apply to be part of the Digital Plan. Our empirical strategy takes advantage of a neat natural experiment that compares the outcomes of students in eligible applying schools that, in a given year, were randomly selected to participate in the plan to receive equipment to the outcomes of students in eligible applying schools that did not receive equipment. We perform balance checks on a rich and extensive set of school- and student-level covariates and verify that balanced randomization was indeed achieved when allocation to the treatments was determined. Schools that received digital equipment were granted either individual access (i.e., one tablet per Grade 7 student) or shared access (i.e., typically one tablet per 3 or 4 Grade 7 students). Over the three years of the program, approximately 3,000 schools (approximately 50% of all schools in France) eventually participated in the plan.

We combine administrative data on all schools (both treated and not treated) with rich, and unique, survey data that we conduct on a random subset of 124 public schools. Within each school surveyed, all students in one (randomly selected) Grade 7 class were surveyed, resulting in a final sample of more than 2,900 students. Students were surveyed (and evaluated) for two consecutive years of treatment. We then continue to track approximately 2,300 students once they enter high school, until Grade 11 (aged 17), at which point they have made choices concerning their educational track (and, in particular, their fields of specialization).

We contribute to the literature by providing, within a single setting, a comprehensive causal analysis of the impact of ICT skills on a large representative sample. We show that the provision of digital tools in the classroom facilitates important learning gains. Treatment has a positive effect on all academic (cognitive) skills. The effects are stronger after the second year of treatment. The impact on sociocognitive skills is mixed, such that, while we see improvements in collaborative capabilities, there is a decline in students' creativity. The equipment type matters, as the impact of individual treatment is larger than that of shared access. Additionally, the treatment has a lasting impact beyond the treatment period: we observe an impact on later test scores on national exams as well as on college-relevant choices. The program also has heterogeneous effects across meaningful dimensions, such that digital tools can complement or substitute for certain user or instructor skills and characteristics.

More specifically, with respect to student skills in the short and medium term, we explore the impact of ICT provision on five dimensions of cognitive or sociocognitive outcomes. We

³The 'priority education' networks, established in 1982, aim to improve the education quality for the socially disadvantaged by allocating additional resources to schools in low-SES areas.

find a positive effect on students' cognitive skills in math and French and on their digital skills. In terms of magnitude, the impact (on average, over two years of treatment) is 16 percent (of a standard deviation of the mean) in French, 11.7 percent in math and 14.1 percent in digital skills. For all skills, we find a sizable impact under both treatment types; however, the magnitudes are generally larger when a student receives an individual tablet than when the student participates in shared access. While the impact on digital skills is stronger after the first year of treatment (with a skills improvement of 29.9 percent under individual access and 24.3 percent under shared access), in French and math, the impact becomes stronger over the two years of treatment (by the end of Grade 8), suggesting that skills needed to 'use' the tools are impacted early but for other skills, there is a cumulative effect over time. In math, by the end of the second year, we find that math skills improve by 24.5 percent in individual treatment and by 18.9 percent in shared treatment. In French, the impact is similar across treatment types, with an increase of approximately 20 percent. With respect to sociocognitive skills, the findings indicate more mixed effects. While the provision of tablets has a positive effect on collaborative capacities, it has a negative effect on students' creativity. Interestingly, collaborative capacities are stronger in the shared access treatment, improving by 14.2 percent, whereas they improve by 9.1 percent (not statistically significant) in the individual access treatment. The decline in creativity is significant only under individual access.

With respect to the longer-term impact of treatment, we link our survey and administrative data to later administrative data, which allows us to track students from middle school into high school. We measure the lasting impact of treatment on student grades on national exams in French and math when they are in Grade 10. We also look at the impact on choices made by students—in particular, for furthering their education, enrolling in the more academic (general) track rather than the vocational track, and course specializations. We find that the effects on national exams taken in Grade 10 in math and French are smaller but continue to be positive, especially for French. Notably, while we do not find any (significant) change after entering high school, we do find a strong and sizable impact on entering the general track, as well as on fields of specialization. Specifically, we find that treated students are more likely to select more technical STEM subjects and are less likely to select more creative art subjects.

Next, we question the effectiveness of the provision of digital tools across different individuals and educational environments. We provide a detailed heterogeneity analysis by student, instructor and school characteristics to help unpack treatment effectiveness and better understand the mechanisms through which these tools achieve their best (and worst) effects. While the analysis of the average treatment effect provides an overview of the im-

pact of ICT on students' skills, the heterogeneity analysis allows us to better assess potential disparities in the effectiveness of increased access to digital tools. Specifically, we explore the heterogeneity in treatment by students' characteristics (gender and socioeconomic background), by school status and by teacher characteristics (gender, experience, qualifications) and (digital) skills.

At the student level, when measuring the impact by gender, we find that the positive effects on cognitive skills are predominantly attributed to female students. Importantly, treatment closes the preexisting gender gaps in math and ICT skills. The impact on female students is also relevant in the longer run, where we observe a lasting treatment impact on choices made in high school. By Grade 11, when students select their fields of specialization, treated female students are more likely to select STEM subjects than are students in the control group.

When we look at the effects of treatment by students' socioeconomic (SES) background, we find that students from different backgrounds are impacted differently by the treatments. While students from higher-SES backgrounds are more likely than students from low-SES backgrounds to benefit from the program in terms of their math scores, low-SES students see relatively more improvements in their French and digital skills. With respect to collaborative capabilities, we find that treatment improves collaboration among students from middle- and high-SES backgrounds but reduces collaboration among students from low-SES backgrounds.

To complement the analysis on students' SES background, we compare the treatment impact in 'priority education' and 'nonpriority education' schools. This comparison allows us to distinguish the school effect from the individual SES effect. Overall, we find a decrease in collaborative skills in priority education schools and an increase in nonpriority schools. Similarly, while we find suggestive evidence of an improvement in digital skills among those in priority education, there is a negligible impact on cognitive skills.

Finally, we explore how the treatment interacts with and complements the characteristics of the teacher. We find that younger teachers and teachers who are on temporary (rather than permanent) contracts are more likely to drive the positive effects in cognitive and digital skills. We also find that ICTs are more frequently used as pedagogical tools in treated classrooms. This finding suggests potential mechanisms for the treatment, as digital tools have a stronger effect when explicitly used in the classroom, and this incorporation into the classroom depends on teacher characteristics.

Our findings contribute to several strands of research. A large body of recent research examines the allocation of digital equipment in the context of the "One Laptop per Child" pro-

gram, often finding no significant impact on academic outcomes. Beuermann et al. (2015), Cristia et al. (2017), and Malamud et al. (2019), for example, use a randomized controlled experiment in Peru with primary school-aged students and find no statistically significant effect on math and language proficiency scores. Similarly, Meza-Cordero (2017), using an RCT in primary schools in Costa Rica, also finds no impact on students' outcomes. In a large-scale program in primary schools in Uruguay, De Melo et al. (2014) also find no effect of one laptop per child program on students' math and reading scores. In another context, Duch and Hull (2017), who use a difference-in-differences strategy with a sample of over 4 million students from Grades 1 to 12 in the U.S., find moderate positive effects on math scores (ranging from a 15% to 17% standard deviation in the medium term). On the other hand, Mora et al. (2018) conducted a longitudinal study on a cohort of more than 170,000 pupils (followed between the ages of 12 and 16) in Catalonia and reported a negative impact of equipment on math and other topics.

Several studies examine the effects of access to a computer at home or at school and similarly find mixed results. Early studies by Fairlie (2005) and Schmitt and Wadsworth (2006) conclude that access to home computers reduces high school drop-out rates and improves test scores, respectively. Similarly, Beltran et al. (2006) find that home computer ownership increases high school graduation but reduces nonproductive activities, such as truancy and crime. More recent findings from a randomized controlled experiment in California involving 1,000 students from Grades 6 to 10 show that having a home computer has no impact on grades or on the results of standardized tests and class attendance (Fairlie and Robinson, 2013). However, the program has a positive effect on students' social interactions, especially on the number of interactions with friends or peers (Fairlie and Kalil, 2017). Malamud and Pop-Eleches (2011) use a regression discontinuity strategy applied to a computer voucher program and found that program participation had a negative effect on students' grades but improved their digital and cognitive skills. Using 15-year-old students' scores in the PISA survey, Agasisti et al. (2020) and Fernandez Gutierrez et al. (2020) similarly identify a negative impact of digital use on students' outcomes. Barrow et al. (2009) examine the allocation of digital equipment in schools using a sample of approximately 2,000 students from Grade 9 and find that the provision of a computer room for math lessons has a statistically significant effect on standardized test scores in algebra. Hence, the literature offers no clear conclusion on the impact of digital equipment provision to middle school students.

Our paper documents, in one large-scale and relevant setting, the effects of digital tools in the classroom on a broad range of student skills. We find sizeable, positive learning gains in cognitive and digital skills, as well as in some dimensions of noncognitive skills, such as collaborative skills, but negative effects on other skills, such as creativity. The richness of

the data allows us to link the treatment to important (career-relevant) long-term effects on educational choices. Some of our key contributions to the literature include the longitudinal design, scale and representation of our experiment, which allows us to offer a comprehensive overview. Another important contribution of our paper is to document the substantial variation in the treatment, depending on the type of classroom access (shared or individual), the length of treatment and the environment. More generally, exploring the heterogeneity in effectiveness by student and instructor characteristics and skills offers insight into potential best practices with these tools. These contributions are both novel with respect to the literature and immensely important from an academic and policy perspective.

This paper is organized as follows. Section 2 describes the design and implementation of the Digital Plan launched in France in 2015. Section 3 describes the administrative and survey data. Section 4 presents the methodology, and Section 5 presents the results of our study. Finally, we conclude the paper in Section 6 and discuss academic and policy implications.

2 Background on the Plan Numrique

2.1 Context

The educational system in France mandates compulsory schooling from the ages of 6 to 16. Elementary education encompasses Grades 1 to 5 and occurs in primary schools, while secondary education covers middle school (from Grades 6 to 9). Until the completion of middle school, nearly all French students adhere to a standardized comprehensive curriculum. After middle school, students can either continue their studies for the last three years in high school (Grades 10 to 12) or enroll in a two-year apprenticeship program.⁴

France has demonstrated a significant commitment to advancing secondary education, allocating a substantial proportion of its GDP, specifically 2.5%, positioning it as the fourth highest among OECD countries. This allocation surpasses the OECD average of 1.9%.⁵ Concerning scholastic achievement in science, math, and reading, France tracks closely with the average level of achievement observed across OECD countries, however, significant dis-

⁴If a student chooses to enter high school, they can opt for one of three tracks: general (academic training), technical (arts/applied sciences/technical training) or professional (vocational training). The general track is typically the path leading to higher education.

⁵OECD (2022), Education spending (indicator).

parities exist.⁶ Notably, France exhibits one of the strongest correlations between the socioeconomic backgrounds of students and their respective test scores.⁷ Similarly, substantial concern has been raised regarding the low levels of socioemotional skills among French adolescents. Namely, among OECD countries, France ranks among the worst in terms of levels of self-confidence, perseverance, anxiety, and discipline.⁸

2.2 Design and Implementation

Launched in 2015, the ‘Digital Plan’ (Plan Numrique) was implemented by the French Ministry of Education for three consecutive years. The primary objective of the plan was to augment the widespread integration of digital technology in middle schools (for students between 13 and 15 years old) across France, equipping educational actors with these tools in a safe environment. Between 2015 and 2017, a total of 3,069 public and private middle schools—approximately 50% of all schools in France—were selected through calls for projects to receive digital equipment (i.e., tablets). In 2017, new calls for the program unexpectedly stopped for political reasons following the national elections.

In Figure 1, we summarize the procedure followed by the plan. Each year, an open call was issued by the French Ministry of Education to middle schools in France, inviting them to apply to be part of the Digital Plan. Schools that applied were evaluated on the basis of their eligibility.⁹ In any given year, the program was oversubscribed. Owing to supply constraints, only a random subset of eligible schools were assigned to treatment (i.e., allocated equipment) in the year they applied. To ensure fairness, this assignment procedure was performed in a nonsystematic (random) way. Among the schools that received digital equipment, they were allocated either individual access (i.e., one tablet per Grade 7 student) or shared access (i.e., typically one tablet per 3 to 4 Grade 7 students).¹⁰ As the policy was unexpectedly stopped in 2017, not all schools that were selected for a given year eventually received digital equipment.

As we describe in the next section, our empirical strategy takes advantage of this natural experiment and compares, within a given year, the outcomes of students in ‘treated’ schools (i.e., eligible applying schools that received equipment) to those of students in ‘con-

⁶OECD (2023), PISA 2022 Results (Volume I): The State of Learning and Equity in Education

⁷OECD (2023), PISA 2022 Results (Volume I) : The State of Learning and Equity in Education

⁸OECD (2021). Beyond Academic Learning: First Results from the Survey on Social and Emotional Skills.

⁹The main eligibility criterion was access to good internet connections and projectors

¹⁰In general, during the initial phase of the plan, it was more common to assign schools individual access. After the first year of the policy, shared access became the predominant form of newly allocated equipment.

trol' schools (i.e., eligible applying schools that did not receive equipment). We present balance checks on a rich and extensive set of school- and student-level covariates and verify that randomization was indeed achieved when the allocation to treatments was determined. In terms of how these digital tools were used and whether the equipment could be used outside of the classroom (i.e., whether students were given permission to take the equipment home), these decisions were made at the school's discretion and without intervention by the administration. In the case of shared equipment, tablets or laptops were available in packs of twelve and could be shared by the entire school, whereby schools set up formal or informal reservation systems to allow the use of this equipment by teachers for individual or collective use in the classroom with students.

3 Data and Sampling

We combine administrative data from all schools (both treated and not treated) with rich, and unique, survey data from a random subset of 124 public schools. Within each school surveyed, all students in one (randomly selected) Grade 7 class were surveyed, resulting in a final sample of more than 2,900 students. Students were surveyed (and examined) for two consecutive years of treatment.¹¹ We then continue to track approximately 2,300 students once they entered high school until Grade 11 (aged 17), at which point they have made choices regarding their educational track (and, in particular, their fields of specialization). In what follows, we detail the various data sources that we combine to evaluate the impact of the Digital Plan on students' achievement. We use administrative data, which allows us to uniquely identify and longitudinally track students and schools. We merge this information with a rich and unique dataset collected by a statistical branch of the Ministry of Education (DEPP - Direction de l'Evaluation, de la Prospective et de la Performance) in partnership with our research team through surveys and assessments to evaluate students and teachers via ad hoc questionnaires.

3.1 Administrative data

Student Data We use the SYSCA (consolidated academic statistical information system for pupils, students and apprentices) database from 2018 to collect information about students' gender, socioeconomic status and place of birth. We complement this information with

¹¹Planned surveys for the third (and last) year of treatment were canceled due to COVID-19.

long-term data from the Sclarite database encompassing high school tracks and optional subjects.

Teacher Data We use the 2017 and 2018 RELAIS database to gather data about teachers’ age, their status (permanent or not) and the subject they teach.¹²

Additional Middle School and High School Data For schools, we use information regarding their participation in the Digital Plan through a specific dataset used by the Ministry of Education to manage the program. Moreover, we gather a wide array of information on middle schools from the 2017 APAE database (public or private schools, priority education or not, number of students and number of teachers at the school level, proportion of students by SES, share of repeaters, average teacher age, average grade at the national middle school final exam, etc.). We use the same database from 2021 for high schools. We supplement this information with sociogeographic data from the National Institute of Statistics and Economic Studies (INSEE) on the population, the poverty rate (i.e., the proportion of individuals whose standard of living is less than 60% of the median standard of living of the French population) and the unemployment rate at the municipality level.

3.2 Surveys and assessment

3.2.1 Initial Short Survey and Sampling

To evaluate the Digital Plan, we collaborated with the Ministry of Education to conduct a targeted survey in December 2017 on the availability and use of digital equipment in middle schools. A questionnaire was distributed to 1,500 schools listed in the plan, asking whether they had received digital equipment and, if so, the access type (i.e., individual or shared). The survey had a 78% response rate (1,062 public schools and 110 private schools).¹³ Table 1 compares the national population of public schools in the Digital Plan with the sample of public schools that responded to this initial survey. Both samples are statistically similar.

In a subsequent phase, using a stratified random sampling method with proportional allocation, 124 public schools were selected for detailed surveys on the basis of school size.

¹²This statistical information system is a consolidation of indirect reports about teachers from schools by local education authorities.

¹³Another sample of 1,500 schools that were not selected for the plan were also surveyed by the Ministry of Education but are not included in this study.

Within each school, one Grade 7 class was randomly chosen, and all the students and their 11 teachers were surveyed. The resulting final sample included 2,949 Grade 7 students and 1,374 teachers for the first period. Among these students, 2,680 were tracked into Grade 8¹⁴, and 2,291 were followed to Grade 10¹⁵, providing a comprehensive longitudinal perspective.¹⁶ Table 2 compares the national population of public schools in Digital Plan with the final sample and shows that both samples are statistically similar.

3.2.2 Detailed Student Surveys

Students in the sample were tracked from Grades 7 to 11 (from 2017 to 2021). Students' skills are measured using the Ministry's standardized tests of math, French oral and written comprehension; digital skills; creativity; and collaboration at the end of Grades 7 and 8. The content of these assessments was produced by one of the Ministry's departments responsible for organizing and monitoring their administration. Below we provide more details on the different assessments.

Cognitive Skills The literacy assessments consisted of a reading comprehension exercise (which is identical for Grades 7 and 8) and oral comprehension exercises. The math assessments covered the entire math curriculum for each grade. The digital skills assessments were developed by a working group led by the DEPP and composed of teachers from different fields (modern literature, math, technology, life and earth sciences) and librarians. These assessments covered the following fields: communication with the digital world, knowledge and respect for the law, digital workspace management, digital identity, materials and networks, algorithmic thinking, and information retrieval. We provide illustrations of all three tests in the appendix (Figures A.1, A.2 and A.3).

Noncognitive Skills Students were also asked in Grades 7 and 8 to respond to scales designed to measure their creativity and collaborative practices. These dimensions were evaluated because the development of these sociocognitive skills is essential for students to evolve in the contemporary world and become citizens in a knowledge-based society (Ananiadou and Claro, 2009). Creativity was measured with two scales: the Karwowski scale (or "Short Scale of Creative Self"), which asks students to position themselves on a Likert scale containing eleven statements related to creativity. Collaboration was measured with a

¹⁴The remaining 269 students either repeated a year or changed schools.

¹⁵the remaining 389 did not go to high school

¹⁶Planned surveys for the third (and last) year of treatment were canceled due to COVID-19.

scale consisting of ten statements about which students were asked to indicate their level of agreement.

3.2.3 Detailed Teacher Survey

In addition to surveying students, teachers of all of the main subjects taught to the students were surveyed¹⁷ The questionnaires covered a wide array of dimensions.¹⁸ However, we focus on three main components: available equipment (at home and at school) to estimate treatment adoption at the school level, digital training and skills and pedagogical practices¹⁹ (see Table A1 in the appendix for a description of the teacher survey).

4 Methodology and Identification

To estimate the causal impact of the provision of digital equipment on students’ outcomes, we compare schools that applied to the Digital Plan program and were (randomly) allocated equipment to those that applied but did not receive equipment. The program was oversubscribed, so not all schools deemed eligible within a given year received digital equipment. Using a centralized system at the Ministry of Education, the provision of digital tools was performed via a nonsystematic, random procedure.

Since allocated schools were chosen randomly to avoid unfairness, there is no selection into treatment.²⁰ In Tables 3 to 8, we present the balance tables (by year) between the eligible schools that applied and received equipment (i.e., ‘treated’ schools) and those that applied and were eligible did not receive equipment (i.e., ‘control’ schools) on an extensive set of relevant observed individual characteristics of students, their teachers and their schools. We confirm that randomization was achieved and that there were no significant differences between schools that received equipment and those that did not receive equipment in a given year.

¹⁷School principals were also surveyed.

¹⁸As the survey contained a large number of questions, we summarized the information in the form of continuous variables through factor analysis to construct a large array of indicators and facilitate analysis and interpretation.

¹⁹Other dimensions not covered here are collaboration and creativity.

²⁰Schools that apply to the program (in a given year) may differ from schools that do not apply. However, since the analysis compares only schools that apply, this difference is not a concern. Moreover, Table 1 shows that the applicant schools are highly representative of national public middle schools and thus allow us to establish a robust sense of external validity.

Treatment varied such that schools that received digital equipment were (randomly) granted either individual access (i.e., one tablet per Grade 7 student) or shared access (i.e., typically one tablet per 3 to 4 Grade 7 students). We examine the schools separately by treatment type and show that allocation to a given treatment was also performed nonsystematically, with no evidence of differences in characteristics by treatment.

In our analysis, we compare each group of students who have access to a given type of equipment (individual or shared access) with a group of students who do not have access to any type of equipment. We also separately measure the impact of individual access and shared access. Thus, we simplify the statistical analysis by using methods with a single binary treatment. The assignment of student i to treatment k ($k = 0, 1, 2$) in school s when in Grade j ($j = 7, 8$) is indicated by the binary variable $T \in (k, i, s, j)$. The notations for the treatment states k are as follows:

T_{0isj} takes a value of 1 if student i enrolled in school s does not have access to any digital equipment (individual or shared) in Grade j ($j = 7, 8$) and 0 otherwise.

T_{1isj} takes a value of 1 if student i enrolled in school s has access to individual digital equipment in Grade j ($j = 7, 8$) and 0 otherwise.

T_{2isj} takes a value of 1 if student i enrolled in school s has access to shared digital equipment in Grade j ($j = 7, 8$) and 0 otherwise.

Consequently, there are three potential outputs (test scores), denoted Y_{0isjl}, Y_{1isjl} and Y_{2isjl} , for a test score denoted l in Grade j ($j = 7, 8$). We analyze the impact of treatment on three types of cognitive skills (math, digital, and French) and two noncognitive skills (creativity and collaboration). The identifiability of the average treatment effect on the treated groups is based on two crucial assumptions: (1) the ignorability assumption and (2) the common support assumption.

The ignorability assumption states that the distributions of potential outcomes are independent of the treatment variables T_{kisj} , conditional on a set of confounding variables X_{is} (i.e., observable covariates characterizing the student i and the school s)²¹ This assumption can be expressed as follows:

²¹Student characteristics: gender, grade acceleration or repetition, born in France, SES (low, middle, high or very high). School characteristics: year of participation in the Plan numrique, priority education zone, number of students at the school level, share of students by SES, delay rate in Grade 6, average teacher age, average grade at middle school final exam, achievement gap of low SES students, and municipal population

$$(Y_{0isjl}, Y_{1isjl}, Y_{2isjl}) \perp\!\!\!\perp (T_{0isj}, T_{1isj}, T_{2isj}) | X_{is} \quad \forall i = 1, ?, N \quad (1)$$

Under this assumption, it can be shown that, for any student i with potential test scores $(Y_{0isjl}, Y_{1isjl}, Y_{2isjl})$ in Grade 7 or 8:

$$(Y_{0isjl}, Y_{kisjl}) \perp\!\!\!\perp (T_{kisj}) | (\Pi_k(X_{is})) \quad \text{for any } k = 1, 2 \quad (2)$$

with $\Pi_k(X_{is}) = Pr(T_{kisj} = 1 | X_{is})$. This result helps to estimate the average treatment effect, which is defined as $E[Y_{kisjl} - Y_{0isjl} | T_{kisj}]$ for any $k = 1, 2$.

The second assumption, the common support assumption, required for identifiability can be expressed as follows:

$$0 < Pr(T_{kisj} = 1 | X_{is}) < 1, \quad \forall k = 1, 2, \quad \forall i = 1, ?, n, \quad \forall s, \quad \forall j = 7, 8 \quad (3)$$

Tables 3 to 8 show that both of these conditions do indeed hold. As an additional check on randomization, we complement our analysis by reweighting observations via the entropy balancing method (Hainmueller, 2012) as a means to balance the distribution of observable covariates in the treatment and control groups, especially in the upper and lower tails of the covariates' distributions.²² Although the balance tables suggest that randomization was performed well on a large set of relevant observable characteristics, the balancing method can help further perform randomization. The entropy balancing method supports the best balance between the observable variables used during pairing.²³ Throughout the analysis, we estimate both least squares and those based on entropy balancing weights.

²²Entropy balancing relies on a maximum entropy reweighting scheme that calibrates unit weights so that the reweighted treatment and control group satisfy a potentially large set of prespecified balance conditions that incorporate information about known sample moments. Entropy balancing therefore exactly adjusts inequalities in representation with respect to the first, second, and possibly higher moments of the covariate distributions (Hainmueller, 2012). Zhao and Percival(2017) show that entropy balancing is doubly robust in linear outcome regression and logistic propensity score regression and that it reaches the asymptotic semiparametric variance bound when both regressions are correctly specified.

²³The set of covariates used includes the following at the school level: year of participation in Plan Numrique, priority education zone, number of students at the school level, share of students by SES, delay rate in Grade 6, average teacher age, average grade at middle school final exam, achievement gap of low SES students, municipal population; at the student level: gender, grade acceleration or repetition, born in France, SES (low, middle, high or very high); at the teacher level: gender, age, status, subject taught; and at the principal level: gender, age, seniority in school. We implement this method in each period (i.e., schooling year).

5 Results

In this section, we present the results of the empirical analysis. We first present the results on the overall treatment effect of the impact of ICT on student outcomes across different treatments and in each year of treatment. In section 5.3, we analyze whether the treatment has a lasting impact on later student outcomes and choices. Finally, in section 5.4, we investigate the interaction of treatment with different student, school and teacher characteristics.

5.1 Overall Impact of Treatment

Table 10 shows the program impact over two years, across both treatments (individual and shared), on cognitive and noncognitive skills. We estimate separate regressions for the five different outcomes (math, French, digital skills, creativity and collaboration). Each row presents the treatment effect when combining treatments (Column (1)) and for each treatment separately (Columns (2) and (3)). The regressions include baseline covariates and weights. The full set of regressions is presented in the Online Appendix, Tables A2 to A6.

In Column (1), when both treatments are combined, students with equipment tend to perform better than those without equipment in terms of their cognitive skills. The gaps in average performance in math, French and digital skills are approximately 11.5 percent, 16.0 percent and 14.0 percent, respectively. In terms of other skills, the effects are more mixed. We find that collaboration improves (11.6 percent), while there is a negative impact on creativity (a fall by around 9 percent).

In Columns (2) and (3), when we examine the results by treatment type, we find that the effects on cognitive skills are generally stronger when students have access to individual equipment than when they have access to shared equipment. In the individual treatment, math scores improved by 17.7 percent, whereas they improved by 6 percent (not statistically significant) for the shared treatment.) The digital skills and French scores are significant in both treatment types, although the point estimates are larger in the case of individual treatment (16 versus 9.1 percent for digital skills and 17.1 versus 14.0 percent for French skills). Furthermore, collaboration skills improved more in schools with shared equipment (14.2 percent) than in schools with individual equipment (9.1 percent, not statistically significant). This finding is in line with the way that equipment is used: shared equipment is generally used collectively. The negative impact on creativity is fully driven by individual equipment.

We can conclude that having access to an individual tablet increases student performance in math, French and digital skills. Shared equipment also improves student test scores but to a lesser extent. The opposite is true for collaboration, which only increases with shared equipment.

5.2 Dynamic Effects of Treatment

Table 11 presents the results separately for each year of treatment by treatment type. The first year of treatment corresponds to Grade 7, and the second year corresponds to Grade 8. Columns (1) and (2) present the results of individual and shared treatment in Grade 7, respectively. Columns (3) and (4) present the results of individual and shared treatment in Grade 8, respectively.

Regarding the overall impact, we see that the impact on cognitive skills is greater for individual treatment than for shared treatment. However, interesting patterns emerge in the cumulative effects. In French, while for the individual treatment, the impact is similar over time (approximately 20 percent), in the shared treatment, there is an insignificant impact in the first year. In contrast, there is a large (20.8 percent) impact by the end of the second year. In math, there is no significant impact in the first year; however, there is a sizable impact in the second year for both treatment types (24.5 percent in the individual treatment and 18.9 percent in the shared treatment). For digital skills, however, we see the opposite impact. While the initial learning of digital skills is important for both types of treatment (29.9 percent in the individual treatment and 24.3 percent in the shared treatment), it has a smaller impact in the second year (12.8 percent in the individual treatment and (nonsignificant) 4.9 percent in the shared treatment). These important findings suggest that different skills are acquired at different stages. Furthermore, they suggest potential interactions across skills. It may be that improved digital skills are a prerequisite that allows students to make the most of the tools and improve other, more academic skills.

With respect to noncognitive skills, when examining the results by treatment type, the effects are smaller and less statistically significant but consistent, and stable patterns emerge. There is a decrease in students' creativity by 19.3 percent in the individual treatment, which remains negative until the second year (11.9 percent), but it is no longer statistically significant. The effects are less negative in the shared treatment and not significant. In terms of collaboration, the coefficients are large and positive across treatment and years, but they are not statistically significant.

Overall, the dynamic effects of treatment suggest that students first learn to use the tools and then other skills improve, perhaps because of improvements in digital skills.

5.3 Long-Term Effects: The Lasting Impact of Treatment

In this section, we study the link between increased access to ICT in middle school and later educational choices and outcomes. We measure the impact of treatment on students' academic test scores on national exams in Grade 10 and their college-relevant educational track and course choices in high school (by Grade 12) several years after they participated in the Digital Plan (in Grade 7). Using administrative data, we track students into high schools to determine whether there is a lasting posttreatment impact.

In Table 12, we report the results for performance on the national exams in math and French. Column (1) presents the results for both treatments, while Columns (2) and (3) present the results separately by equipment type. Overall, although we do not find a lasting impact of treatment on math scores, we do see a continued positive impact on performance in French.

In terms of choices of tracks and courses (Table 12), we find some noteworthy lasting impacts, especially in STEM subject choices. While there is no impact on entering high school, there is a greater likelihood of entering the general track (rather than the vocational track). Moreover, when selecting subjects (which are relevant for later university-related choices), we find a greater likelihood of taking math subjects, which is consistent with our findings that treatment has a stronger impact on math scores during treatment. Similarly, we observe a lower likelihood of taking art subjects, which is consistent with our findings that treatment has a negative impact on creativity scores during treatment.

In terms of gender, as shown in Table A13, the math and STEM findings are particularly strong for female students. This result is particularly important, as the OECD has highlighted the gender digital divide; namely, only 24 percent of graduates in engineering, manufacturing and construction are women, and ICT skills can help narrow the gender wage gap (OECD, 2018). As we report in the next section, the impact of ICT skills is more generally important for female students.

Overall, the analysis in this section highlights the important lasting impact of access to digital tools in middle school, as well as the strong interaction of treatments with the choice of STEM subjects.

5.4 Heterogeneous Treatment Effects

To understand the complementarity and substitutability of digital tools with respect to pre-existing gaps, skills and resources, we analyze the heterogeneity in treatment by student, school and instructor characteristics. While the analysis of the average treatment effect provides a good overview of the impact of ICT on students' skills, treatment effect heterogeneity is crucial for understanding who benefits from (or potentially is negatively impacted by) the treatment. Understanding the variation in treatment allows us to better assess potential disparities in the effectiveness of increased access to digital tools. We explore the heterogeneity in the treatment by gender, social background and teacher characteristics and skills. Each column represents a different outcome. We combine the two treatment types and two time periods.

5.4.1 Students' Gender

To understand gender differences in labor market outcomes, there is increasing interest in studying differences in the educational domain. A particular focus has been given to the underrepresentation of women in STEM and its connection to the gender pay gap (for an overview of the literature, see Bertrand, 2020). Differences in learning styles and choices of technology-related fields, as well as early gender stereotypes and biases with respect to ICT tools, call into question the origins of STEM-related choices. In this section, we ask whether increased access to ICT in the classroom impacts male and female students differently.

Table 13 presents the impact of the treatment on female versus male students. Overall, we find that the impact on cognitive skills is generally stronger for female students, especially in math. In Appendix B.3 (Tables A7, A8, A9, A10, A11), we see that the effects are similarly large across both waves and equipment types. Importantly, the analysis shows that having access to digital tools closes the existing gap between male and female students in math, as the coefficient of the interaction between being a female student and receiving the treatment nearly compensates for the negative coefficient of being a female student. Indeed, during the first period, the difference between male and female students in math in the control group is equal to 53.2 percent while it is close to zero in schools with individual equipment and 16.2 percent in the schools with shared equipment.

Equally important, we find that the treatment closes gender gaps in digital skills. In the control group, female students have lower scores in digital skills than male students do (9 percent), while the opposite is true in the treatment groups (the difference in favor of

female students is 21 percent in the schools with individual equipment and 13.9 percent in the schools with shared equipment). The differences are qualitatively similar in the second period.

A potential takeaway from the analysis is that by changing the norms concerning the use of digital tools and making them more accessible and prevalent in the classroom, female students employ them more, improving their digital skills. These improved skills in turn enhance their (academic) skills, especially in math. The findings may also partially reflect differential prior use or access to digital tools.²⁴ As we will discuss later, treatment has a lasting impact, with increased choice of math (and more generally, STEM) courses in high school.

5.4.2 Students' Social Background

An important question that motivates this analysis is whether improved ICT access in the classroom can help reduce inequality in learning. The digital divide has changed in recent years, with access to digital technology being more equal than before. However, there are now different types of tools (e.g., smartphones versus tablets) and different modes of access, in particular, the integration of tools with in-class learning as well as potential differences in instructors across schools serving students from different social backgrounds.

In Table 14, we explore potential heterogeneity in the treatment by socioeconomic background. While for most outcomes, we do not find important differences in effectiveness by background, some notable results emerge from this analysis. In particular, we find that the impact is larger (especially in math) for the students in the higher-SES group. Moreover, with respect to collaboration, we actually see a *negative* effect of increased digital access on students in the lower-SES group and a *positive* effect on the higher-SES group. While we find suggestive evidence of an improvement in digital skills, the results are not statistically significant. These important findings may suggest that students from more disadvantaged backgrounds may not use digital tools in a way that would allow them to fully exploit them, which may exacerbate the already large differences in learning across social groups.

Finally, to distinguish the school effect from individuals' social background, we compare the impact of treatment in schools deemed 'priority' versus 'nonpriority' education. 'Priority

²⁴Survey data on use suggest that although female students are more likely to use digital tools frequently to look for information about schoolwork online and to communicate with other students about homework (51% and 44%, respectively) than male students are (44% and 41%, respectively), the opposite is true for communication with teachers (5% of female students and 9% of male students), and there is no significant difference in ICT use for general homework

education’ networks, established in 1982, aimed to improve the education quality for the socially disadvantaged by allocating additional resources to schools in low-SES areas. Table 15 shows that the impact of treatment is smaller in ‘priority’ school schools, and while for most outcomes, there is no significant impact, we do see a detrimental impact on collaboration. These findings are in line with our findings at the individual level. Similarly, while we find suggestive evidence of an improvement in digital skills among those in priority education, there is a negligible effect on cognitive skills.

5.4.3 Teachers’ Characteristics

Perhaps the most important mechanism through which increased access to digital tools impacts students’ skills is their use in classroom instruction. In section ??, we show that there is considerable treatment take-up by teachers. However, an important question relates to how the technology is used and whether the (digital) skills and characteristics of the instructors play a role in its effectiveness.

In Table 16, we study the interaction of treatment with teachers’ characteristics (age/experience, gender, contract type). Specifically, we restrict the analysis to teachers in the subjects of math, French and technology (digital), for which we have students’ cognitive test scores. This analysis shows that while there is no impact of teacher characteristics in math, for both French and technology, teacher characteristics can play a role in treatment effectiveness. In particular, younger teachers and teachers on temporary contracts use digital tools more effectively.

Turning to teachers’ digital skills, training and pedagogical practices, we find that teachers adapt their teaching practices when digital tools are available. From Table 17, we see that while digital skills do not impact the effectiveness of students’ outcomes, we do see a shift in teachers’ practices, especially in schools that received individual equipment. Namely, teachers use digital tools more frequently for course preparation and for learning activities performed by students in the classroom. We do not observe a similar effect with shared equipment.

The appropriation of digital tools by teachers in their practices is a potential mechanism explaining the impact of tablets on student learning, particularly the greater impact of individual tablets. This hypothesis is reinforced by students’ self-reported ICT use. While being in any treatment group increases student use in the classroom, as reported in section ??, we do not observe a similar effect on student use at home. Hence, we can assume

that teachers’ practices in the classroom are detrimental for generating positive effects from the use of digital equipment. However, it is necessary to design a study to estimate the causal relationship between teachers’ pedagogical practices with digital technology and their students’ results to confirm the causal chain.

6 Conclusion

Using a large-scale, nationally representative experiment on the integration of digital tools in the classroom, this study offers comprehensive insight into their effectiveness for improving students’ skills and their lasting impact. Random assignment to the Digital Plan, a program in France that provides tablets (either shared or individual access) to middle schools for students in Grade 7, included approximately 3,000 schools (i.e., 50 percent of all schools in France) over the three years of the program. Combining administrative data and rich (unique) survey data from a randomly selected sample of schools, we show that the provision of digital tools in French middle schools effectively improved students’ academic and digital skills, as well as their collaborative capabilities. However, there is a negative impact on students’ creativity. When we explore other dimensions, we find that in terms of treatment, individual access is more effective than shared access. Similarly, over the two years of treatment, while the first year is important for improving digital skills, other skills are more strongly impacted in the second year. Several years later, we see a lasting (positive) impact of treatment on national exams in Grade 10 and on college-relevant choices by Grade 12, especially within STEM disciplines.

To understand potential disparities across students (and schools) concerning the effectiveness of increased ICT in the classroom, our study allows for a detailed investigation of a wide spectrum of interactions. Motivated by the potential equality factors surrounding digital technology, especially in the classroom, such as the access gap to ICT related to social background (the ‘digital divide’) or the underrepresentation of female students in technology-related fields, we explore heterogeneity in terms of students’ sociodemographic characteristics. We show that female students respond more to treatment than male students do, which partially reflects differences in access prior to treatment. The differential impact of gender is highly important. The treatment helps close the gender gaps in math and digital skills, and importantly, we find that treated female students are more likely to choose STEM or technical courses later in high school. With regard to social background, while for digital and language skills, there are no statistically significant differences across students, we find that important positive effects on math skills and collaboration skills are

largely observed in students from more advantaged backgrounds, suggesting that in trying to equalize digital access, existing gaps in learning are exacerbated.

To explore the potential mechanism through which increased access to digital tools impacts students' skills, we study teachers' characteristics, digital skills and pedagogical practices. As classroom instructors choosing to employ these tools, they demonstrate enormous take-up of digital tools. Moreover, we show important interactions between the treatments and the teachers. Younger teachers and teachers on temporary contracts use the digital tools more effectively. Similarly, teachers who adapt their practices and use digital tools more frequently for course preparation have a greater impact.

When launched in 2015, the French government allocated a total of 750 million euros to the Digital Program, which meant (on average) 250 million euros per year, with an initial target of 3,069 schools in total. With an average of 121 students per grade in each school, we estimate that approximately 373,435 students were equipped, such that the individual cost would be 670 euros per student. From a policy perspective, given this increased public investment in digital equipment for schools, our study helps inform the link between digital tools and student skills, as well as their later educational decisions and outcomes.

It is crucial to understand the role played by increased access to modern technology and modes of learning in developing a broad set of skills, especially when through the public provision. Similarly, understanding how dispersed the impacts are across students, as well as the role played by instructors or schools more generally, is important for improved targeted policies. We have shown that there are clear learning gains from improved access to digital tools in the classroom. Teachers and the learning environment seem to be key drivers of the effectiveness of these tools, suggesting that investments in teachers' digital skills could help further improve their effectiveness. Similarly, having individual versus shared access in the classroom seems to matter. While shared access is effective and can improve collaboration with classmates, individual access has a stronger impact, especially in the longer run. Our analysis also suggests that the policy could target certain students—female students and students from lower socioeconomic backgrounds show disproportionate gains in important dimensions, such as improvements in digital skills.

Overall, our study provides insight into the black box of the provision of technology and—given the critical role of both cognitive and noncognitive skills for later economic success and general well-being—helps further our understanding of the emergence and persistence of inequality.

REFERENCES

References

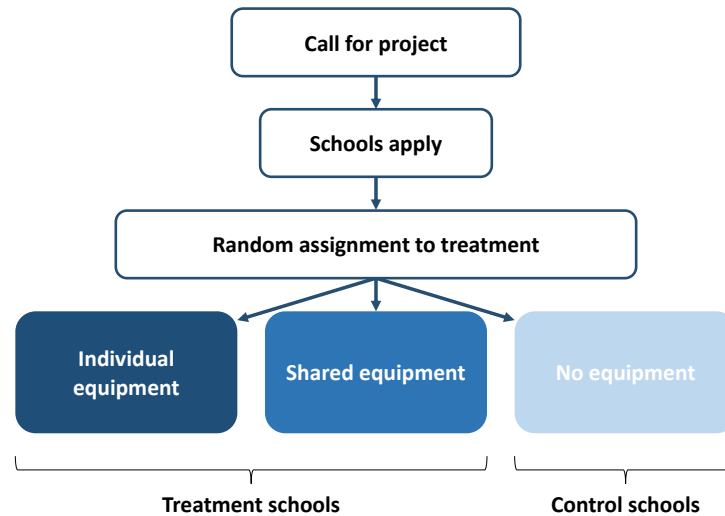
- [1] AGASISTI, T., GIL-IZQUIERDO, M., AND HAN, S. W. Ict use at home for school-related tasks: What is the effect on a students achievement? empirical evidence from oecd pisa data. *Education Economics* 28, 6 (2020), 601–620.
- [2] BARRERA-OSORIO, F., AND LINDEN, L. L. *The use and misuse of computers in education: evidence from a randomized experiment in Colombia*. The World Bank, 2009.
- [3] BARROW, L., MARKMAN, L., AND ROUSE, C. E. Technology’s edge: The educational benefits of computer-aided instruction. *American Economic Journal: Economic Policy* 1, 1 (2009), 52–74.
- [4] BELTRAN, D., DAS, K., AND FAIRLIE, R. W. Do home computers improve educational outcomes? evidence from matched current population surveys and the national longitudinal survey of youth 1997.
- [5] BEUERMANN, D. W., CRISTIA, J., CUETO, S., MALAMUD, O., AND CRUZ-AGUAYO, Y. One laptop per child at home: Short-term impacts from a randomized experiment in peru. *American Economic Journal: Applied Economics* 7, 2 (2015), 53–80.
- [6] CRISTIA, J., IBARRARAN, P., CUETO, S., SANTIAGO, A., AND SEVERIN, E. Technology and child development: Evidence from the one laptop per child program. *American Economic Journal: Applied Economics* 9, 3 (2017), 295–320.
- [7] DE MELO, G., MACHADO, A., AND MIRANDA, A. The impact of a one laptop per child program on learning: Evidence from uruguay. *Available at SSRN 2505351* (2014).
- [8] ESCUETA, M., NICKOW, A. J., OREOPOULOS, P., AND QUAN, V. Upgrading education with technology: Insights from experimental research. *Journal of Economic Literature* 58, 4 (2020), 897–996.
- [9] FAIRLIE, R. W. The effects of home computers on school enrollment. *Economics of Education review* 24, 5 (2005), 533–547.
- [10] FAIRLIE, R. W., AND KALIL, A. The effects of computers on children’s social development and school participation: Evidence from a randomized control experiment. *Economics of Education Review* 57 (2017), 10–19.

- [11] FAIRLIE, R. W., AND LONDON, R. A. The effects of home computers on educational outcomes: Evidence from a field experiment with community college students. *The Economic Journal* 122, 561 (2012), 727–753.
- [12] FAIRLIE, R. W., AND ROBINSON, J. Experimental evidence on the effects of home computers on academic achievement among schoolchildren. *American Economic Journal: Applied Economics* 5, 3 (2013), 211–40.
- [13] FALCK, O., MANG, C., AND WOESSMANN, L. Virtually no effect? different uses of classroom computers and their effect on student achievement. *Oxford Bulletin of Economics and Statistics* 80, 1 (2018), 1–38.
- [14] FERNANDEZ-GUTIERREZ, M., GIMENEZ, G., AND CALERO, J. Is the use of ict in education leading to higher student outcomes? analysis from the spanish autonomous communities. *Computers & Education* 157 (2020), 103969.
- [15] FOR ECONOMIC CO-OPERATION, O., AND (OECD), D. Bridging the digital gender divide: Include, upskill, innovate. *OECD* (2018).
- [16] HAINMUELLER, J. Entropy balancing for causal effects: A multivariate reweighting method to produce balanced samples in observational studies. *Political analysis* 20, 1 (2012), 25–46.
- [17] HAINMUELLER, J., AND XU, Y. Ebalance: A stata package for entropy balancing. *Journal of Statistical Software* 54, 7 (2013).
- [18] HULL, M., AND DUCH, K. One-to-one technology and student outcomes.
- [19] KARWOWSKI, M., LEBUDA, I., WISNIEWSKA, E., AND GRALEWSKI, J. Big five personality traits as the predictors of creative self-efficacy and creative personal identity: Does gender matter? *The Journal of Creative Behavior* 47, 3 (2013), 215–232.
- [20] MALAMUD, O., CUETO, S., CRISTIA, J., AND BEUERMAN, D. W. Do children benefit from internet access? experimental evidence from peru. *Journal of Development Economics* 138 (2019), 41–56.
- [21] MALAMUD, O., AND POP-ELECHES, C. Home computer use and the development of human capital. *The Quarterly journal of economics* 126, 2 (2011), 987–1027.
- [22] MEZA-CORDERO, J. A. Learn to play and play to learn: Evaluation of the one laptop per child program in costa rica. *Journal of International Development* 29, 1 (2017), 3–31.

- [23] MORA, T., ESCARDIBUL, J. O., AND DI PIETRO, G. Computer and students achievement: An analysis of the one laptop per child program in catalonia]. *International Journal of Educational Research* 92 (2018), 145–157.
- [24] SCHMITT, J., AND WADSWORTH, J. Is there an impact of household computer ownership on children’s educational attainment in britain? *Economics of Education review* 25, 6 (2006), 659–673.

7 Figures

Figure 1: School Assignment to Treatment (within a year)



Notes: Each year between 2015 to 2017, inclusive, an open call is issued by the French Ministry of Education to middle schools, inviting them to apply to be part of the Digital Plan. Within each year, schools would apply and if deemed eligible would be randomly assigned to one of three groups: Individual equipment (i.e., each grade 7 student receives a tablet), shared equipment (i.e., classroom receives one tablet per 3-4 students), or no equipment. Schools are assigned in a comparison group by 2017.

8 Tables

Table 1: National Population of Public Middle Schools in the Digital Plan vs. Sample of Schools Responding to First Survey

	National	Survey	p
Priority education			
No	2051 (76.1)	815 (76.7)	0.697
Yes	645 (23.9)	247 (23.3)	
Proportion of students by SES			
Very high	16.3 (11.7)	16.3 (11.3)	0.906
High	11.3 (4.8)	11.4 (4.9)	0.777
Middle	26.0 (7.9)	26.2 (7.6)	0.509
Low	40.6 (15.4)	40.4 (15.0)	0.637
No. of students	506.4 (203.2)	498.1 (201.0)	0.254
Average teacher age	41.7 (3.4)	41.9 (3.3)	0.067*
Average GPA in national final exam	10.5 (1.4)	10.6 (1.3)	0.056*
Average municipal population (K.)	32.2 (54.4)	31.4 (57.4)	0.684
Average unemployment rate	9.2 (1.9)	9.2 (1.8)	0.791
Poverty rate	17.8 (8.4)	17.8 (8.4)	0.861
Number of observations	2696	1062	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. *Priority education* are schools in less affluent areas that receive additional resources. *Proportion of students by SES* are proportion of students by socio-economic status. *No. of students* are the number of students at the school. *Average teacher age* is the average age (in years) of teachers at the school. *Average GPA in national final exam* is the schools average GPA in the national middle school final exam. *Average municipal population* is the municipal population in thousands. *Average unemployment rate* is average municipal unemployment rate. *Poverty rate* is the municipal proportion of people whose standard of living is less than 60% of the median standard of living of the French population. The significance of differences is based on a chi-square test for categorical variables and a F-test for continuous variables.

Table 2: National Population of Public Middle Schools in the Digital Plan vs. Random Sample Selected for Detailed Survey

	National	Sample	p
Priority education			
No	2051 (76.1)	95 (76.6)	0.976
Yes	645 (23.9)	29 (23.4)	
Proportion of students by SES			
Very high	16.3 (11.7)	17.0 (11.1)	0.498
High	11.3 (4.8)	11.5 (4.7)	0.612
Middle	26.0 (7.9)	26.8 (6.4)	0.256
Low	40.6 (15.4)	38.6 (14.0)	0.14
No. of students	506.4 (203.2)	526.0 (175.3)	0.292
Average teacher age	41.7 (3.4)	42.0 (3.2)	0.32
Average GPA at national final exam	10.5 (1.4)	10.5 (1.4)	0.89
Average municipal population (K.)	32.2 (54.4)	30.7 (44.2)	0.758
Average unemployment rate	9.2 (1.9)	9.5 (2.3)	0.03*
Poverty rate	17.8 (8.4)	17.3 (8.1)	0.498
Number of observations	2696	124	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a F-test for continuous variables. For further definitions of the variables, see Table 1.

Table 3: Balance Tables: *Individual Equipment* Treatment (year, 2015)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	44.118	43.478	0.639
Not in Priority education zone	55.882	56.522	-0.639
No. students	454.735	460.087	-5.352
No. teachers	33.215	33.895	-0.680
No. classes with > 28 students	2.441	1.304	1.137
Social composition of the school (%)			
Low	42.991	44.648	-1.657
Middle	26.079	25.730	0.349
High	8.912	9.839	-0.927
Very high	14.056	13.070	0.986
Percentage of girls	49.759	49.209	0.550
Average teacher age	41.344	41.217	0.127
Average GPA at national final exam	9.847	10.217	-0.370
Achievement gap by SES	4.662	6.322	-1.660
Repetition rate by grade 6	9.615	10.617	-1.002
Municipal population (in K.)	75.277	29.642	45.635*
Unemployment rate	9.617	9.414	0.202
Poverty rate	19.170	20.082	-0.912
Number of observations	34	23	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. *Priority education* are schools in less affluent areas that receive additional resources. *No. students* are number of students at the school. *No. teachers* are number of teachers at the school. *No. classes with > 28 students* are the number of classes at school with more than 28 students. *Social composition of the school* are proportion of students with low, middle, high, very high, respectively, socio-economic status at the school. *Average teacher age* is the average age (in years) of teachers at the school. *Average GPA in national final exam* is the schools average GPA in the national middle school final exam. *Achievement gap by SES* is the gap in GPA between the lowest and highest SES groups. *Repetition rate by grade 6* is the proportion of students who repeated at least on grade when they reach grade 6. *Average municipal population* is the municipal population in thousands. *Average unemployment rate* is average municipal unemployment rate. *Poverty rate* is the average municipal proportion of people whose standard of living is less than 60% of the median standard of living of the French population. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables.

Table 4: Balance Tables: *Shared Equipment* Treatment (year, 2015)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	51.220	43.478	7.741
Not in Priority education zone	48.780	56.522	-7.741
No. students	463.902	460.087	3.815
No. teachers	34.065	33.895	0.169
No. classes with > 28 students	1.415	1.304	0.110
Social composition of the school (%)			
Low	47.402	44.648	2.755
Middle	23.771	25.730	-1.960
High	10.083	9.839	0.244
Very high	10.922	13.070	-2.148
Percentage of girls	49.839	49.209	0.630
Average teacher age	40.741	41.217	-0.476
Average GPA at national final exam	10.037	10.217	-0.181
Achievement gap by SES	4.715	6.322	-1.607
Repetition rate by grade 6	10.544	10.617	-0.073
Municipal population (in K.)	33.644	29.642	4.002
Unemployment rate	9.232	9.414	-0.182
Poverty rate	21.205	20.082	1.124
Number of observations	41	23	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables. For further definitions of the variables, see Table 3.

Table 5: Balance Tables: *Individual Equipment* Treatment (year, 2016)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	25.000	25.373	-0.373
Not in Priority education zone	75.000	74.627	0.373
No. students	564.176	531.876	32.301
No. teachers	38.328	36.444	1.884
No. classes with > 28 students	3.529	2.687	0.843
Social composition of the school (%)			
Low	35.101	40.542	-5.440*
Middle	26.807	25.394	1.414
High	10.503	11.436	-0.933
Very high	20.643	16.684	3.959
Percentage of girls	48.901	49.289	-0.388
Average teacher age	42.282	41.656	0.627
Average GPA at national final exam	10.354	10.399	-0.044
Achievement gap by SES	5.872	6.390	-0.518
Repetition rate by grade 6	9.329	8.992	0.337
Municipal population (in K.)	42.522	33.344	9.179
Unemployment rate	9.751	9.395	0.356
Poverty rate	16.928	17.639	-0.711
Number of observations	68	201	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables. For further definitions of the variables, see Table 3.

Table 6: Balance Tables: *Shared Equipment* Treatment (year, 2016)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	22.652	25.373	-2.721
Not in Priority education zone	77.348	74.627	2.721
No. students	490.331	531.876	-41.544*
No. teacher	34.160	36.444	-2.284
No. classes with > 28 students	2.039	2.687	-0.648
Social composition of the school (%)			
Low	41.739	40.542	1.197
Middle	25.709	25.394	0.316
High	11.956	11.436	0.519
Very high	15.261	16.684	-1.423
Percentage of girls	49.243	49.289	-0.046
Average teacher age	41.801	41.656	0.145
Average GPA at national final exam	10.648	10.399	0.250
Achievement gap by SES	5.218	6.390	-1.172
Repetition rate by grade 6	8.636	8.992	-0.356
Municipal population (in K.)	31.399	33.344	-1.944
Unemployment rate	9.008	9.395	-0.387
Poverty rate	16.695	17.639	-0.943
Number of observations	181	201	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables. For further definitions of the variables, see Table 3.

Table 7: Balance Tables: *Individual Equipment* Treatment (year, 2017)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	20.000	19.849	0.151
Not in Priority education zone	80.000	80.151	-0.151
No. students	533.143	493.889	39.253
No. teachers	35.273	33.560	1.713
No. classes with > 28 students	3.771	2.025	1.746*
Social composition of the school (%)			
Low	35.609	39.975	-4.366
Middle	25.757	26.660	-0.902
High	12.637	11.516	1.121
Very high	18.917	16.191	2.726
Percentage of girls	48.351	49.260	-0.908
Average teacher age	42.794	41.721	1.073*
Average GPA at national final exam	10.583	10.700	-0.117
Achievement gap by SES	8.209	6.579	1.630
Repetition rate by grade 6	10.031	8.615	1.416
Municipal population (in K.)	31.191	24.830	6.361
Unemployment rate	9.822	8.757	1.065*
Poverty rate	15.209	17.854	-2.646*
Number of observations	35	398	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables. For further definitions of the variables, see Table 3.

Table 8: Balance Tables: *Shared Equipment* Treatment (year, 2017)

	Treated Schools	Control Schools	Difference
School sector (%)			
Priority education zone	19.632	19.849	-0.217
Not in Priority education zone	80.368	80.151	0.217
No. students	493.773	493.889	-0.116
No. teachers	33.703	33.560	0.144
No. classes with > 28 students	2.589	2.025	0.564
Social composition of the school (%)			
Low	39.388	39.975	-0.587
Middle	27.075	26.660	0.415
High	11.610	11.516	0.094
Very high	16.899	16.191	0.708
Percentage of girls	48.979	49.260	-0.281
Average teacher age	42.282	41.721	0.561
Average GPA at national final exam	10.736	10.700	0.036
Achievement gap by SES	6.222	6.579	-0.357
Repetition rate by grade 6	8.299	8.615	-0.317
Municipal population (in K.)	29.453	24.830	4.623
Unemployment rate	9.230	8.757	0.473**
Poverty rate	17.444	17.854	-0.410
Number of observations	163	398	

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. The significance of differences is based on a chi-square test for categorical variables and a student test for continuous variables. For further definitions of the variables, see Table 3.

Table 9: Teachers' Use of Digital Tools (by Treatment Type)

	Any Equipment	Individual Equipment	Shared Equipment
Access to digital equipment in school	0.157 *** (0.041)	0.121 ** (0.051)	0.279 *** (0.056)
Access to digital equipment at home	0.173 *** (0.043)	0.195 *** (0.057)	0.136 ** (0.057)
Reduction of material barriers	0.431 *** (0.047)	0.518 *** (0.062)	0.377 *** (0.06)
Controls	Yes	Yes	Yes
Weights	Yes	Yes	Yes
Wave fixed effects	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each cell contains the results of a separate linear regression. The coefficient reported is the coefficient on treatment. Treatment is equal to 1 if units are treated and 0 if not. In the first column, treated units are teachers in school with any type of equipment, in the second column, treated units are teachers in schools with individual equipment and in the last column, treated units are teachers in schools with shared equipment. Control units are teachers in school with no equipment. Each regression controls for the year of participation to the Digital Plan, student's gender, grade acceleration or repetition, born in France, socio-economic status, school Priority education status, number of students in the school, share of students by socio-economic status in the school, repetition rate by grade 6, average teacher age at the school, average GPA at national exam in middle school, achievement gap of low SES students and city size. Weights are computed by entropy balancing, using the same set of variables as the set of controls.

Table 10: Overall Treatment Impact

	Any Equipment	Individual Equipment	Shared Equipment
French	0.159 *** (0.045)	0.171 *** (0.052)	0.139 *** (0.052)
Math	0.117 ** (0.052)	0.178 *** (0.061)	0.069 (0.056)
Digital skills	0.141 *** (0.053)	0.161 *** (0.061)	0.100 * (0.057)
Creativity	-0.092 (0.064)	-0.121 * (0.072)	-0.058 (0.065)
Collaboration	0.116 * (0.066)	0.091 (0.075)	0.142 ** (0.069)
School characteristics	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes
Weights	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each cell contains the results of a separate linear regression. The coefficient reported is the coefficient on treatment. Treatment is equal to 1 if units are treated and 0 if not. In the first column, treated units are students in schools with any type of equipment, while in the second one, treated units are students in schools with individual equipment, and shared equipment in the last column. Control units are students in school with neither. Each row displays results for a different outcome. Outcomes are students' test scores in Math, Digital skills, French, Creativity and Collaboration, respectively. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9. See Appendix Tables A2 to A6 for full specifications of each outcome (with and without controls, fixed effects and weights).

Table 11: Dynamic Treatment Effect: By Wave and Equipment Type

	First wave		Second wave	
	Individual	Shared	Individual	Shared
	(1)	(2)	(3)	(4)
French	0.165 ** (0.081)	0.091 (0.074)	0.193 *** (0.070)	0.208 *** (0.079)
Math	0.080 (0.097)	-0.030 (0.089)	0.245 *** (0.077)	0.189 *** (0.073)
Digital skills	0.299 *** (0.102)	0.243 ** (0.097)	0.128 * (0.075)	0.049 (0.077)
Creativity	-0.193 * (0.108)	-0.094 (0.111)	-0.119 (0.098)	-0.070 (0.091)
Collaboration	0.153 (0.121)	0.166 (0.107)	0.115 (0.095)	0.079 (0.081)
School characteristics	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes
Wave FE	No	No	No	No
Weights	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each cell contains the results of a separate linear regression. The coefficient reported is the coefficient on treatment. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students with either individual equipment (columns 1 and 3) or shared equipment (columns 2 and 4). Control units are students in school with no mobile digital equipment. Results from the first wave (students in grade 7) are displayed in the first two columns, while results from the second wave (students in grade 8) are displayed in the last two columns. Each row displays results for a different outcome. Outcomes are students' test scores in Math, Digital skills, French, Creativity and Collaboration. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 12: Long-term Treatment Effect

	Any Equipment	Individual Equipment	Shared Equipment
Test scores at beginning of High School			
French	0.118 ** (0.058)	0.114 (0.078)	0.155 ** (0.075)
Math	0.018 (0.062)	0.006 (0.090)	-0.027 (0.090)
Other longterm outcomes			
Go to High School	-0.026 (0.165)	0.172 (0.243)	0.059 (0.225)
General track	0.206 (0.128)	0.314 * (0.184)	0.290 (0.183)
STEM option	0.344 ** (0.144)	0.327 (0.200)	0.623 *** (0.203)
Math option	0.374 ** (0.151)	0.418 ** (0.210)	0.543 ** (0.217)
Art option	-0.295 (0.270)	-0.291 (0.308)	-0.431 (0.380)
School characteristics	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes
Weights	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each cell contains the results of a separate linear regression. The coefficient reported is the coefficient on treatment. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each row displays results for a different outcome. Outcomes are students' test scores in Math and French at the beginning of High School, or other long term outcomes. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 13: Heterogeneous Treatment Effect: Student Gender

	French	Math	Digital skills	Creativity	Collaboration
Constant	-1.171 *** (0.393)	-0.961 * (0.494)	0.008 (0.475)	0.511 (0.652)	0.504 (0.697)
Treatment	0.092 (0.065)	-0.099 (0.070)	0.042 (0.077)	-0.137 (0.089)	0.081 (0.093)
Gender (Ref.: Male)					
Female	0.084 (0.073)	-0.416 *** (0.085)	-0.010 (0.083)	-0.184 * (0.111)	0.116 (0.107)
Interaction Treatment*Gender (Ref.: Male)					
Treatment*Female	0.136 * (0.081)	0.434 *** (0.093)	0.200 ** (0.090)	0.087 (0.119)	0.068 (0.115)
Number of observations	3925	3756	3796	2641	2905
R	0.149	0.158	0.162	0.032	0.043
School characteristics	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores in French, Math, Digital skills, Creativity and Collaboration. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 14: Heterogeneous Treatment Effect: Student Socioeconomic Status

	French	Math	Digital skills	Creativity	Collaboration
Constant	-1.260 *** (0.394)	-1.153 ** (0.497)	-0.149 (0.497)	0.441 (0.660)	0.593 (0.672)
Treatment	0.126 (0.088)	-0.048 (0.097)	0.157 (0.098)	-0.085 (0.146)	-0.208 * (0.109)
Socio-economic status (Ref.: Low)					
Middle	0.134 (0.098)	0.181 * (0.108)	0.223 * (0.115)	0.108 (0.154)	-0.251 * (0.137)
High	0.320 *** (0.097)	0.094 (0.118)	0.236 ** (0.109)	0.074 (0.158)	-0.107 (0.129)
Interaction Treatment*Socio-economic status (Ref.: Low)					
Treatment*Middle	-0.020 (0.106)	0.027 (0.115)	-0.110 (0.121)	-0.092 (0.171)	0.451 *** (0.147)
Treatment*High	0.073 (0.106)	0.329 *** (0.124)	0.042 (0.119)	0.047 (0.171)	0.371 *** (0.138)
Number of observations	3925	3756	3796	2641	2905
R	0.142	0.141	0.159	0.031	0.048
School characteristics	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores in Math, Digital skills, French, Creativity and Collaboration. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 15: Heterogeneous Treatment Effect: Priority Education Schools

	French	Math	Digital skills	Creativity	Collaboration
Constant	-1.267 *** (0.392)	-1.102 ** (0.484)	0.053 (0.464)	0.443 (0.653)	0.307 (0.690)
Treatment	0.129 ** (0.052)	0.095 * (0.055)	0.076 (0.056)	-0.138 * (0.070)	0.205 *** (0.076)
In priority education (Ref.: No)					
Yes	-0.076 (0.127)	-0.390 *** (0.139)	-0.525 *** (0.152)	-0.143 (0.181)	0.266 * (0.153)
Interaction Treatment*In priority education (Ref.: No)					
Treatment*Yes	0.119 (0.131)	0.048 (0.150)	0.264 (0.162)	0.154 (0.197)	-0.490 *** (0.161)
Number of observations	3925	3756	3796	2641	2905
R	0.146	0.149	0.163	0.032	0.051
School characteristics	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores in Math, Digital skills, French, Creativity and Collaboration. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 16: Heterogeneous Treatment Effect: Teachers' Characteristics

	French	Math	Technology
Constant	-0.182 (0.500)	-0.588 (0.585)	-0.452 (0.548)
Treatment	0.430 *** (0.091)	0.238 ** (0.105)	0.187 * (0.101)
Teacher gender (Ref. : Male)			
Female	0.106 (0.125)	-0.028 (0.119)	-0.055 (0.122)
Teacher age (Ref. : Below the median)			
Above the median	0.391 *** (0.126)	0.035 (0.131)	0.220 * (0.130)
Teacher status (Ref. : Permanent)			
Temporary	-0.353 ** (0.177)	-0.094 (0.197)	-0.408 ** (0.192)
Interactions			
Treatment*F: Female Teacher	-0.007 (0.133)	0.069 (0.132)	0.119 (0.132)
Treatment* Age group: Above the median	-0.411 *** (0.138)	-0.061 (0.142)	-0.334 ** (0.144)
Treatment* Status: Temporary	0.388 * (0.213)	0.111 (0.222)	0.434 * (0.229)
Number of observations	1958	1916	1931
R	0.17	0.143	0.16
School characteristics	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes
Wave FE	No	No	No
Weights	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome, during the second wave. We regress students' test scores in French, Math and Digital skills on their French, Math and Technology teachers' characteristics (teachers' age, gender and qualification), respectively, during the second wave (grade 8). We take into account the treatment status. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Table 17: Heterogeneous Treatment Effect: Teachers' Skills and Practices

	Any Equipment	Individual Equipment	Shared Equipment
Teacher digital literacy			
Digital skills	0.023 (0.047)	0.039 (0.062)	0.047 (0.063)
Self-reported digital literacy	0.060 (0.038)	0.091 * (0.051)	0.004 (0.050)
On-the-job training	-0.096 ** (0.044)	-0.047 (0.057)	-0.149 *** (0.057)
Teacher professional and teaching practices			
Reduction of material barriers	0.431 *** (0.047)	0.518 *** (0.062)	0.377 *** (0.060)
Digital tools for course preparation	0.136 *** (0.043)	0.193 *** (0.055)	0.100 * (0.058)
Digital pedagogical use by students	0.142 *** (0.044)	0.256 *** (0.057)	-0.009 (0.060)
Controls	Yes	Yes	Yes
Weights	Yes	Yes	Yes
Wave fixed effects	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Standard errors are displayed in brackets. Each cell contains the results of a separate linear regression. The coefficient reported is the coefficient on treatment. Treatment is equal to 1 if units are treated and 0 if not. In the first column, treated units are teachers in school with any type of equipment, in the second column, treated units are teachers in schools with individual equipment and in the last column, treated units are teachers in schools with shared equipment. Control units are teachers in school with no equipment. Each row displays results for a different outcome. Outcomes are teachers' indices from the teacher questionnaire. All columns display results of weighted linear regressions with controls. All regressions include set of controls. For further definitions of controls, see Table 9.

Appendices

A Appendix - Figures

A.1 Illustration of student tests

Figure A.1: An item from the test in French

The screenshot shows a digital test interface. At the top, a dark bar contains the text 'EVALUATION ELAINE Séquence 1' on the left and a progress indicator with '25%' on the right. Below this, a dark header reads 'L'île 1/10'. The main content area is divided into two sections. On the left, a text box contains a story in French: 'Le sieur Trelawney, le docteur Livesey et le reste de ces messieurs m'ayant demandé de noter toute l'histoire de l'île au Trésor, du début jusqu'à la fin, sans rien omettre si ce n'est l'emplacement exact de l'île, et cela seulement parce qu'il s'y trouve encore du trésor, je prends ma plume, et je reviens au temps où mon père tenait l'auberge de "L'Amiral Benbow" et où le vieux marin balafre est venu loger sous notre toit. Je me souviens de lui comme si c'était hier, avançant à pas lourds vers la porte de l'auberge. D'après Robert Luis Stevenson, L'île au trésor, 1882'. On the right, a question box asks 'Dans la suite de cette histoire, il sera question :'. Below the question are four radio button options: 'de la pollution d'une île.', 'd'une plume mystérieuse.', 'd'une belle plume en or.', and 'd'un trésor caché dans une île.'. At the bottom of the text box, it says 'Page 1 / 1'.

Figure A.2: An item from the test in Math

The screenshot shows a digital test interface. At the top, a dark bar contains the text 'EVALUATION ELAINE Séquence 2' on the left and a progress indicator with '86%' on the right. Below this, a dark header reads 'Somme de fractions'. The main content area contains a math problem: $\frac{5}{4} + \frac{7}{6} =$. Below the problem is a large text box containing five radio button options: $\frac{12}{10}$, $\frac{60}{24}$, $\frac{29}{12}$, $\frac{29}{24}$, and $\frac{29}{24}$.

Figure A.3: An item from the test in Digital skills

EVALUATION ELAINE Séquence 2 32%

Communiquer avec le numérique

Utiliser et produire des documents multimédia.
Connaître les formats d'image

**Vous faites une recherche sur le thème des chats. Vous trouvez plusieurs fichiers sur ce sujet.
Lequel est un fichier image ?**

chat.doc

chat.odt

chat.jpg

chat.mp4

B Appendix - Tables

B.1 Description of teacher survey

Table A1: Description of teachers' indices

Index	Description	Scale
Digital skills	Objective measure of teacher's digital skills	Correct or incorrect answer
Self-reported digital literacy	Teacher's self-reported digital literacy, based on objective information (initial training related to ICT) and subjective information (ease and knowledge) ? only technical aspects	Strongly disagree (1) to strongly agree (5)
On-the-job training	On-the-job training on digital technology in relation to teaching, both based on the type of training (online, etc.) and about the content (how to use tools, use of digital technology, etc.). There is no time limit for this training.	Yes or No
Diversity of equipment at home	Teachers' digital equipment at home. The questions ask about the different types of equipment teachers have at home.-	Yes or No
Diversity of equipment at school	Diversity of digital equipment to which the teacher has access in the school. The questions concern the different types of equipment to which teachers have access to at the school	Yes or No
Digital tools for course preparation	Frequency of use of digital tools for class preparation and creating teaching sequences, through online information search, use of digital resources, etc. Students are not always required to use digital tools themselves during the sequences.	Never (1) to Everyday (5)
Use of digital tools by students	Frequency of use of digital tools by students, in class independently or in a supervised mode, and outside of class, at the request of the teacher.	Never (1) to Everyday (5)

Reduction of material barriers	Material obstacles encountered by the teacher in using digital use of digital technology in their teaching. These obstacles are linked to lack of tools, their obsolescence or maintenance issues.	Strongly disagree (1) to strongly agree (5)
Reduction of personal barriers	Personal obstacles encountered by the teacher to the use of digital technology in their teaching. These obstacles are linked to a low level of proficiency and negative personal beliefs about digital technology in the classroom.	Strongly disagree (1) to strongly agree (5)
Self-efficacy knowledge of technology and pedagogy	? Self-efficacy about their mastery of technological tools in order to improve their teaching practices, particularly with regard to their ability to choose the digital tools adapted to different teaching situations.	Strongly disagree (1) to strongly agree (5)
Self-efficacy knowledge of technology, pedagogy and content	? Teacher's self-efficacy in using technological tools to improve both the content delivered to students and the methods used to deliver it. In particular, the teacher's ability to choose and use digital tools to illustrate the content of the course and to optimize teaching.	Strongly disagree (1) to strongly agree (5)
Digital collaboration	Collaborative practices between teachers with the use of digital tools. It covers different types of activities that can be carried out collectively by the team within the school, such as student assessment, preparation for training courses, etc.	Never (1) to Everyday (5)

B.2 Detailed overall results

Table A2: Detailed results - French - all types of equipment

	(1)	(2)	(3)	(4)	(5)
Constant	-0.067 (0.051)	-0.747* (0.320)	-1.009** (0.318)	-1.009** (0.318)	-1.242*** (0.325)
Treatment	0.203*** (0.041)	0.199*** (0.043)	0.200*** (0.042)	0.200*** (0.042)	0.159*** (0.031)
Selected into the Plan numérique (ref.: in 2015)					
in 2016	-0.013 (0.040)	-0.031 (0.043)	-0.017 (0.042)	-0.019 (0.042)	-0.044 (0.049)
in 2017	0.108** (0.041)	0.066 (0.046)	0.056 (0.045)	0.054 (0.045)	-0.097* (0.050)
Gender (ref.: Boy):					
Girl			0.189*** (0.031)	0.189*** (0.030)	0.151*** (0.029)
Grade (ref.: On time)					
Repetition			-0.483*** (0.054)	-0.484*** (0.054)	-0.530*** (0.053)
Acceleration			0.557*** (0.098)	0.556*** (0.098)	0.600*** (0.097)
Born in France (ref.: No)					
Yes			0.151* (0.068)	0.151* (0.068)	0.184** (0.067)
Socio-economic stat (ref.: Low)					
Middle			0.123** (0.043)	0.123** (0.043)	0.126** (0.041)
High			0.253*** (0.053)	0.253*** (0.053)	0.186*** (0.050)
Very high			0.476*** (0.053)	0.476*** (0.053)	0.450*** (0.050)

	(1)	(2)	(3)	(4)	(5)
			(0.048)	(0.048)	(0.045)
Sector (ref.: Not in priority education)					
In priority education		-0.091° (0.054)	-0.054 (0.053)	-0.055 (0.053)	-0.003 (0.054)
City size (ref.: less than 2K.)					
More than 200K.		-0.010 (0.083)	0.020 (0.081)	0.018 (0.081)	-0.379*** (0.076)
Between 20K. and 200K.		0.121 (0.081)	0.127 (0.079)	0.127 (0.079)	-0.377*** (0.074)
Between 2K. and 20K.		-0.120 (0.075)	-0.118 (0.073)	-0.118 (0.073)	-0.458*** (0.070)
Number of students		-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Social composition of the school (%)					
Middle SES		-0.000 (0.003)	-0.002 (0.003)	-0.002 (0.003)	-0.012*** (0.003)
High SES		0.005 (0.004)	0.002 (0.004)	0.002 (0.004)	0.008* (0.004)
Very high SES		0.009*** (0.002)	0.003 (0.002)	0.003 (0.002)	-0.005° (0.003)
Share of repeaters in grade 6		0.012* (0.006)	0.014* (0.006)	0.014* (0.006)	0.023*** (0.005)
Teacher average age		-0.010 (0.006)	-0.008 (0.006)	-0.008 (0.006)	-0.004 (0.006)
Average grade at middle school national exam		0.080*** (0.018)	0.073*** (0.018)	0.073*** (0.018)	0.146*** (0.018)
Achievement gap at middle school national exam		0.008** (0.003)	0.010*** (0.003)	0.010*** (0.003)	0.010** (0.003)
School characteristics	No	Yes	Yes	Yes	Yes
Individual characteristics	No	No	Yes	Yes	Yes
Wave FE	No	No	No	Yes	Yes

	(1)	(2)	(3)	(4)	(5)
Weights	No	No	No	No	Yes
R ²	0.007	0.047	0.127	0.128	0.147
Adj. R ²	0.007	0.044	0.122	0.123	0.142
Num. obs.	4084	4084	3925	3925	3925

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column contains the results of a separate linear regression. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each column displays results for a different specification. We always control for the Year of participation to the Plan numrique. School characteristics include: school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Individual characteristics include : student's gender, grade acceleration or repetition, born in France and socio-economic status (low, middle, high, very high). Weights are computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

Table A3: Detailed results - Math - all types of equipment

	(1)	(2)	(3)	(4)	(5)
Constant	-0.041 (0.055)	-1.181*** (0.332)	-1.238*** (0.334)	-1.250*** (0.333)	-1.164*** (0.351)
Treatment	0.074° (0.044)	0.117** (0.045)	0.116** (0.044)	0.119** (0.044)	0.117*** (0.034)
Selected into the Plan numrique (ref.: in 2015)					
in 2016	-0.093* (0.043)	-0.036 (0.045)	-0.031 (0.045)	-0.040 (0.045)	-0.126* (0.054)
in 2017	0.108* (0.044)	0.125** (0.048)	0.098* (0.048)	0.094* (0.048)	-0.031 (0.055)
Gender (ref.: Boy):					
Girl			-0.058° (0.032)	-0.057° (0.032)	-0.202*** (0.031)
Grade (ref.: On time)					
Repetition			-0.434*** (0.058)	-0.437*** (0.058)	-0.459*** (0.058)
Acceleration			0.633*** (0.102)	0.633*** (0.102)	0.778*** (0.103)
Born in France (ref.: No)					

	(1)	(2)	(3)	(4)	(5)
Yes			-0.010 (0.070)	-0.011 (0.070)	-0.001 (0.071)
Socio-economic stat (ref.: Low)					
Middle			0.181*** (0.046)	0.182*** (0.046)	0.198*** (0.044)
High			0.194*** (0.056)	0.196*** (0.056)	0.022 (0.054)
Very high			0.454*** (0.050)	0.456*** (0.050)	0.389*** (0.048)
Sector (ref.: Not in priority education)					
In priority education		-0.333*** (0.056)	-0.308*** (0.056)	-0.309*** (0.056)	-0.348*** (0.058)
City size (ref.: less than 2K.)					
More than 200K.		-0.206* (0.086)	-0.176* (0.086)	-0.181* (0.085)	-0.258** (0.082)
Between 20K. and 200K.		-0.042 (0.085)	-0.022 (0.084)	-0.022 (0.083)	-0.106 (0.080)
Between 2K. and 20K.		-0.049 (0.078)	-0.014 (0.077)	-0.014 (0.077)	-0.028 (0.076)
Number of students		0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Social composition of the school (%)					
Middle SES		-0.001 (0.003)	-0.003 (0.003)	-0.004 (0.003)	-0.010** (0.003)
High SES		-0.003 (0.004)	-0.005 (0.004)	-0.005 (0.004)	-0.007 (0.004)
Very high SES		0.016*** (0.002)	0.010*** (0.002)	0.010*** (0.002)	0.006* (0.003)
Share of repeaters in grade 6		0.021*** (0.006)	0.025*** (0.006)	0.026*** (0.006)	0.035*** (0.006)
Teacher average age		0.009	0.010	0.010	-0.002

	(1)	(2)	(3)	(4)	(5)
Average grade at middle school national exam		(0.007) 0.037°	(0.007) 0.036°	(0.007) 0.036°	(0.007) 0.116***
Achievement gap at middle school national exam		(0.019) 0.006*	(0.019) 0.007*	(0.019) 0.007*	(0.019) 0.004
		(0.003)	(0.003)	(0.003)	(0.003)
School characteristics	No	Yes	Yes	Yes	Yes
Individual characteristics	No	No	Yes	Yes	Yes
Wave FE	No	No	No	Yes	Yes
Weights	No	No	No	No	Yes
R ²	0.007	0.084	0.135	0.138	0.147
Adj. R ²	0.006	0.080	0.130	0.132	0.142
Num. obs.	3905	3905	3756	3756	3756

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column contains the results of a separate linear regression. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each column displays results for a different specification. We always control for the Year of participation to the Plan numrique. School characteristics include: school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Individual characteristics include : student's gender, grade acceleration or repetition, born in France and socio-economic status (low, middle, high, very high). Weights are computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

Table A4: Detailed results - Digital skills - all types of equipment

	(1)	(2)	(3)	(4)	(5)
Constant	-0.004 (0.052)	-0.265 (0.314)	-0.427 (0.314)	-0.432 (0.314)	-0.087 (0.334)
Treatment	0.071° (0.042)	0.143*** (0.042)	0.144*** (0.041)	0.145*** (0.041)	0.141*** (0.032)
Selected into the Plan numrique (ref.: in 2015)					
in 2016	-0.084* (0.040)	0.017 (0.043)	0.022 (0.042)	0.019 (0.042)	-0.069 (0.052)
in 2017	0.048 (0.042)	0.055 (0.046)	0.031 (0.045)	0.029 (0.045)	-0.071 (0.052)

	(1)	(2)	(3)	(4)	(5)
Gender (ref.: Boy):					
Girl			0.151*** (0.030)	0.151*** (0.030)	0.088** (0.030)
Grade (ref.: On time)					
Repetition			-0.529*** (0.055)	-0.530*** (0.055)	-0.636*** (0.056)
Acceleration			0.724*** (0.096)	0.724*** (0.096)	0.709*** (0.099)
Born in France (ref.: No)					
Yes			0.080 (0.066)	0.080 (0.066)	0.157* (0.068)
Socio-economic stat (ref.: Low)					
Middle			0.140** (0.043)	0.141** (0.043)	0.179*** (0.042)
High			0.218*** (0.052)	0.219*** (0.052)	0.161** (0.052)
Very high			0.362*** (0.047)	0.363*** (0.047)	0.325*** (0.046)
Sector (ref.: Not in priority education)					
In priority education		-0.287*** (0.053)	-0.261*** (0.053)	-0.262*** (0.053)	-0.334*** (0.055)
City size (ref.: less than 2K.)					
More than 200K.		-0.313*** (0.081)	-0.290*** (0.080)	-0.292*** (0.080)	-0.396*** (0.078)
Between 20K. and 200K.		-0.070 (0.080)	-0.061 (0.078)	-0.061 (0.078)	-0.226** (0.076)
Between 2K. and 20K.		-0.062 (0.073)	-0.045 (0.072)	-0.045 (0.072)	-0.149* (0.072)
Number of students		-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)

	(1)	(2)	(3)	(4)	(5)
Social composition of the school (%)					
Middle SES		-0.004 (0.003)	-0.006* (0.003)	-0.006* (0.003)	-0.013*** (0.003)
High SES		-0.001 (0.004)	-0.004 (0.004)	-0.004 (0.004)	-0.006 (0.004)
Very high SES		0.017*** (0.002)	0.012*** (0.002)	0.012*** (0.002)	0.007* (0.003)
Share of repeaters in grade 6		0.016** (0.006)	0.020*** (0.006)	0.020*** (0.006)	0.019*** (0.006)
Teacher average age		-0.010 (0.006)	-0.009 (0.006)	-0.009 (0.006)	-0.021** (0.006)
Average grade at middle school national exam		0.050** (0.018)	0.043* (0.018)	0.043* (0.018)	0.093*** (0.018)
Achievement gap at middle school national exam		0.008** (0.003)	0.009** (0.003)	0.009** (0.003)	0.008** (0.003)
School characteristics	No	Yes	Yes	Yes	Yes
Individual characteristics	No	No	Yes	Yes	Yes
Wave FE	No	No	No	Yes	Yes
Weights	No	No	No	No	Yes
R ²	0.004	0.081	0.148	0.148	0.159
Adj. R ²	0.003	0.077	0.143	0.143	0.154
Num. obs.	3947	3947	3796	3796	3796

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column contains the results of a separate linear regression. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each column displays results for a different specification. We always control for the Year of participation to the Plan numrique. School characteristics include: school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Individual characteristics include : student's gender, grade acceleration or repetition, born in France and socio-economic status (low, middle, high, very high). Weights are computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

Table A5: Detailed results - Creativity - all types of equipment

	(1)	(2)	(3)	(4)	(5)
Constant	0.052 (0.064)	-0.111 (0.401)	0.093 (0.417)	0.104 (0.416)	0.482 (0.443)
Treatment	-0.049 (0.049)	-0.062 (0.052)	-0.070 (0.052)	-0.074 (0.052)	-0.092* (0.042)
Selected into the Plan numrique (ref.: in 2015)					
in 2016	-0.041 (0.051)	-0.040 (0.055)	-0.044 (0.056)	-0.050 (0.056)	-0.074 (0.070)
in 2017	-0.056 (0.052)	-0.023 (0.058)	-0.022 (0.059)	-0.019 (0.059)	-0.018 (0.071)
Gender (ref.: Boy):					
Girl			-0.100* (0.039)	-0.100* (0.039)	-0.142*** (0.039)
Grade (ref.: On time)					
Repetition			-0.178* (0.073)	-0.176* (0.073)	-0.223** (0.076)
Acceleration			0.112 (0.123)	0.112 (0.123)	0.527*** (0.126)
Born in France (ref.: No)					
Yes			-0.170° (0.091)	-0.173° (0.091)	-0.398*** (0.094)
Socio-economic stat (ref.: Low)					
Middle			0.025 (0.056)	0.028 (0.056)	0.066 (0.056)
High			0.107 (0.068)	0.110 (0.068)	0.082 (0.068)
Very high			0.116° (0.061)	0.121* (0.061)	0.103° (0.060)

	(1)	(2)	(3)	(4)	(5)
Sector (ref.: Not in priority education)					
In priority education		-0.001 (0.067)	-0.003 (0.068)	-0.009 (0.068)	-0.069 (0.073)
City size (ref.: less than 2K.)					
More than 200K.		0.056 (0.100)	0.046 (0.103)	0.043 (0.103)	0.021 (0.102)
Between 20K. and 200K.		-0.028 (0.096)	-0.037 (0.098)	-0.034 (0.098)	-0.023 (0.096)
Between 2K. and 20K.		0.044 (0.090)	0.039 (0.092)	0.037 (0.092)	0.059 (0.093)
Number of students		0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Social composition of the school (%)					
Middle SES		0.002 (0.004)	0.002 (0.004)	0.002 (0.004)	-0.002 (0.004)
High SES		-0.004 (0.005)	-0.005 (0.005)	-0.005 (0.005)	-0.001 (0.006)
Very high SES		-0.002 (0.003)	-0.003 (0.003)	-0.003 (0.003)	-0.001 (0.004)
Share of repeaters in grade 6		-0.001 (0.007)	0.001 (0.007)	0.001 (0.007)	0.003 (0.007)
Teacher average age		0.013 (0.008)	0.011 (0.008)	0.010 (0.008)	0.013 (0.009)
Average grade at middle school national exam		-0.045* (0.022)	-0.039° (0.023)	-0.040° (0.023)	-0.058* (0.024)
Achievement gap at middle school national exam		0.003 (0.004)	0.003 (0.004)	0.003 (0.004)	0.001 (0.004)
School characteristics	No	Yes	Yes	Yes	Yes
Individual characteristics	No	No	Yes	Yes	Yes
Wave FE	No	No	No	Yes	Yes
Weights	No	No	No	No	Yes

	(1)	(2)	(3)	(4)	(5)
R ²	0.001	0.007	0.015	0.017	0.031
Adj. R ²	-0.000	0.001	0.006	0.008	0.023
Num. obs.	2730	2730	2641	2641	2641

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column contains the results of a separate linear regression. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each column displays results for a different specification. We always control for the Year of participation to the Plan numrique. School characteristics include: school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Individual characteristics include : student's gender, grade acceleration or repetition, born in France and socio-economic status (low, middle, high, very high). Weights are computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

Table A6: Detailed results - Collaboration - all types of equipment

	(1)	(2)	(3)	(4)	(5)
Constant	-0.050 (0.060)	-0.518 (0.369)	-0.791* (0.380)	-0.792* (0.380)	0.483 (0.411)
Treatment	0.046 (0.046)	0.067 (0.049)	0.067 (0.049)	0.066 (0.049)	0.116** (0.039)
Selected into the Plan numrique (ref.: in 2015)					
in 2016	-0.032 (0.047)	-0.012 (0.051)	-0.007 (0.052)	-0.007 (0.052)	-0.048 (0.066)
in 2017	0.087° (0.049)	0.103° (0.054)	0.086 (0.055)	0.086 (0.055)	0.066 (0.066)
Gender (ref.: Boy):					
Girl			0.172*** (0.036)	0.172*** (0.036)	0.150*** (0.037)
Grade (ref.: On time)					
Repetition			-0.293*** (0.066)	-0.293*** (0.066)	-0.390*** (0.070)
Acceleration			0.170 (0.113)	0.170 (0.113)	0.090 (0.119)
Born in France (ref.: No)					

	(1)	(2)	(3)	(4)	(5)
Yes			0.148° (0.082)	0.147° (0.082)	0.040 (0.088)
Socio-economic stat (ref.: Low)					
Middle			0.089° (0.052)	0.089° (0.052)	-0.029 (0.053)
High			0.134* (0.063)	0.134* (0.063)	0.044 (0.064)
Very high			0.193*** (0.056)	0.194*** (0.056)	0.091 (0.057)
Sector (ref.: Not in priority education)					
In priority education		-0.096 (0.062)	-0.085 (0.062)	-0.086 (0.062)	-0.028 (0.068)
City size (ref.: less than 2K.)					
More than 200K.		-0.127 (0.095)	-0.088 (0.096)	-0.089 (0.096)	-0.197* (0.097)
Between 20K. and 200K.		-0.051 (0.091)	-0.029 (0.092)	-0.029 (0.092)	-0.098 (0.093)
Between 2K. and 20K.		-0.062 (0.085)	-0.028 (0.086)	-0.028 (0.086)	-0.150° (0.089)
Number of students		0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Social composition of the school (%)					
Middle SES		-0.006° (0.003)	-0.007* (0.003)	-0.007* (0.003)	-0.015*** (0.004)
High SES		-0.005 (0.005)	-0.008 (0.005)	-0.008 (0.005)	-0.011* (0.005)
Very high SES		0.003 (0.003)	0.000 (0.003)	0.000 (0.003)	0.001 (0.003)
Share of repeaters in grade 6		-0.003 (0.007)	0.001 (0.007)	0.001 (0.007)	-0.006 (0.007)
Teacher average age		0.013°	0.012	0.012	-0.006

	(1)	(2)	(3)	(4)	(5)
Average grade at middle school national exam		(0.007) 0.006	(0.007) 0.009	(0.007) 0.008	(0.008) 0.016
Achievement gap at middle school national exam		(0.021) 0.005	(0.021) 0.006°	(0.021) 0.006°	(0.023) 0.007°
		(0.003)	(0.003)	(0.003)	(0.004)
School characteristics	No	Yes	Yes	Yes	Yes
Individual characteristics	No	No	Yes	Yes	Yes
Wave FE	No	No	No	Yes	Yes
Weights	No	No	No	No	Yes
R ²	0.003	0.016	0.042	0.042	0.043
Adj. R ²	0.002	0.011	0.035	0.035	0.035
Num. obs.	2992	2992	2905	2905	2905

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column contains the results of a separate linear regression. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. Each column displays results for a different specification. We always control for the Year of participation to the Plan numrique. School characteristics include: school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Individual characteristics include : student's gender, grade acceleration or repetition, born in France and socio-economic status (low, middle, high, very high). Weights are computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

B.3 Detailed results by gender

Table A7: Overview of results by Gender - Waves and equipment type separately - French

	All types of equipment		Individual		Shared	
	First wave	Second wave	First wave	Second wave	First wave	Second wave
Constant	-1.445 **	-0.992 **	-3.061 ***	0.690	-2.049 ***	0.290
	(0.618)	(0.490)	(0.649)	(0.559)	(0.604)	(0.669)
Treatment	0.059	0.166 *	0.101	0.136	0.101	0.149
	(0.093)	(0.086)	(0.111)	(0.099)	(0.100)	(0.113)
Gender (Ref.: Male)						
Female	0.132	0.130	0.124	0.134	0.115	0.121
	(0.109)	(0.094)	(0.122)	(0.109)	(0.108)	(0.115)
Interaction Treatment*Gender (Ref.: Male)						
Treatment*Female	0.051	0.120	0.128	0.117	-0.020	0.118
	(0.119)	(0.106)	(0.140)	(0.125)	(0.130)	(0.136)
Number of observations	1763	2162	1117	1449	1001	1122
R	0.15	0.188	0.135	0.177	0.131	0.213
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, student's gender, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with Weights computed by entropy balancing, using the same set of variables as the set of controls.

Table A8: Overview of results by Gender - Waves and equipment type separately - Math

	All types of equipment		Individual		Shared	
	First wave	Second wave	First wave	Second wave	First wave	Second wave
Constant	-1.324 *	-0.711	-1.254 *	0.682	-1.635 ***	-0.660
	(0.679)	(0.673)	(0.676)	(0.596)	(0.619)	(0.573)
Treatment	-0.302 ***	0.023	-0.249 **	0.087	-0.284 **	-0.006
	(0.108)	(0.090)	(0.125)	(0.102)	(0.118)	(0.099)
Gender (Ref.: Male)						
Female	-0.651 ***	-0.256 **	-0.665 ***	-0.262 **	-0.654 ***	-0.232 **
	(0.133)	(0.110)	(0.150)	(0.118)	(0.129)	(0.116)
Interaction Treatment*Gender (Ref.: Male)						
Treatment*Female	0.572 ***	0.359 ***	0.660 ***	0.326 **	0.483 ***	0.393 ***
	(0.143)	(0.119)	(0.168)	(0.133)	(0.150)	(0.135)
Number of observations	1637	2119	1036	1419	912	1114
R	0.17	0.173	0.142	0.17	0.207	0.169
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, student's gender, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with Weights computed by entropy balancing, using the same set of variables as the set of controls.

Table A9: Overview of results by Gender - Waves and equipment type separately - Digital skills

	All types of equipment		Individual		Shared	
	First wave	Second wave	First wave	Second wave	First wave	Second wave
Constant	0.266 (0.815)	-0.151 (0.609)	-0.695 (0.723)	1.038 * (0.566)	-1.257 * (0.721)	-0.273 (0.550)
Treatment	0.136 (0.138)	0.029 (0.097)	0.197 (0.145)	0.059 (0.112)	0.126 (0.142)	-0.01 (0.116)
Gender (Ref.: Male)						
Female	-0.044 (0.149)	0.073 (0.105)	-0.025 (0.156)	0.102 (0.116)	-0.122 (0.140)	0.083 (0.117)
Interaction Treatment*Gender (Ref.: Male)						
Treatment*Female	0.188 (0.157)	0.149 (0.114)	0.203 (0.169)	0.143 (0.129)	0.221 (0.159)	0.119 (0.135)
Number of observations	1660	2136	1049	1431	926	1121
R	0.163	0.167	0.188	0.164	0.194	0.175
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, student's gender, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with Weights computed by entropy balancing, using the same set of variables as the set of controls.

Table A10: Overview of results by Gender - Waves and equipment type separately - Creativity

	All types of equipment		Individual		Shared	
	First wave	Second wave	First wave	Second wave	First wave	Second wave
Constant	0.962 (0.837)	0.387 (0.919)	0.745 (0.827)	-0.740 (0.807)	1.091 (0.792)	1.218 (0.744)
Treatment	-0.296 ** (0.127)	-0.050 (0.122)	-0.368 *** (0.138)	-0.134 (0.143)	-0.211 (0.137)	-0.076 (0.129)
Gender (Ref.: Male)						
Female	-0.333 ** (0.169)	-0.096 (0.152)	-0.321 * (0.170)	-0.188 (0.169)	-0.313 * (0.166)	-0.094 (0.149)
Interaction Treatment*Gender (Ref.: Male)						
Treatment*Female	0.287 (0.182)	-0.036 (0.162)	0.341 * (0.196)	0.034 (0.183)	0.223 (0.191)	0.012 (0.171)
Number of observations	1055	1586	609	1035	697	853
R	0.046	0.038	0.073	0.06	0.047	0.045
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, student's gender, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with Weights computed by entropy balancing, using the same set of variables as the set of controls.

Table A11: Overview of results by Gender - Waves and equipment type separately - Collaboration

	All types of equipment		Individual		Shared	
	First wave	Second wave	First wave	Second wave	First wave	Second wave
Constant	0.392 (1.001)	0.065 (0.851)	0.449 (0.940)	0.665 (0.778)	0.888 (0.840)	-0.563 (0.738)
Treatment	-0.055 (0.134)	0.146 (0.117)	-0.055 (0.159)	0.104 (0.135)	-0.029 (0.139)	0.093 (0.124)
Gender (Ref.: Male)						
Female	-0.163 (0.180)	0.187 (0.129)	-0.151 (0.180)	0.140 (0.144)	-0.072 (0.172)	0.142 (0.148)
Interaction Treatment*Gender (Ref.: Male)						
Treatment*Female	0.422 ** (0.196)	-0.042 (0.138)	0.392 * (0.213)	0.023 (0.157)	0.363 * (0.198)	-0.028 (0.166)
Number of observations	960	1945	538	1303	647	1002
R	0.077	0.055	0.085	0.055	0.091	0.051
School characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, student's gender, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with Weights computed by entropy balancing, using the same set of variables as the set of controls.

Table A12: Longterm results - Cognitive Scores - By Gender

	French	Math
Constant	-1.582 *** (0.538)	-1.776 *** (0.652)
Treatment	0.045 (0.083)	-0.065 (0.090)
Gender (Ref.: Male)		
Female	0.116 (0.094)	-0.279 *** (0.098)
Interaction Treatment*Gender (Ref.: Male)		
Treatment*Female	0.138 (0.104)	0.155 (0.108)
Number of observations	2069	2068
R	0.195	0.237
School characteristics	Yes	Yes
Individual characteristics	Yes	Yes
Wave FE	Yes	Yes
Weights	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are students' test scores in French and Math at national tests in Grade 10, in High school. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numérique, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with weights computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.

Table A13: Longterm results - Other longterm outcomes - By Gender

	Go to High School	General track	STEM option	Math option
Constant	5.178 *** (1.660)	-1.062 (1.200)	-0.907 (1.353)	-0.692 (1.384)
Treatment	0.086 (0.204)	-0.061 (0.173)	0.093 (0.193)	0.057 (0.201)
Gender (Ref.: Male)				
Female	1.046 *** (0.277)	0.177 (0.206)	-0.508 ** (0.230)	-0.686 *** (0.243)
Interaction Treatment*Gender (Ref.: Male)				
Treatment*Female	-0.299 (0.308)	0.518 ** (0.230)	0.500 ** (0.255)	0.653 ** (0.269)
Number of observations	2646	2646	2285	2285
School characteristics	Yes	Yes	Yes	Yes
Individual characteristics	Yes	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes

Notes: * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level. Robust standard errors are displayed in brackets. Each column is a separate linear regression, for a specific outcome. Outcomes are non-cognitive long term outcomes. Treatment is equal to 1 if units are treated and 0 if not. Treated units are students in school with mobile digital equipment. Control units are students in school with no mobile digital equipment. We control for a set of variables: Year of participation to the Plan numrique, grade acceleration or repetition, born in France, socio-economic status (low, middle, high, very high), school Priority education status, number of students in the school, share of students by socio-economic status in the school, delay rate in grade 6, average teacher age at the school level average grade at middle school final exam, achievement gap of low SES students and city size. Regressions are weighted with weights computed by entropy balancing, using the same set of variables as the set of controls. Both waves and both types of equipment (individual or shared) are combined.