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Laura Pagani, Gianluca Argentin, Marco Gui, Luca Stanca

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The Impact of Digital Skills on Educational Outcomes: Evidence from Performance Tests

Laura Pagani*, Gianluca Argentin°, Marco Gui•, Luca Stanca◊

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Abstract

Digital skills are increasingly important for labor market outcomes and social participation. Do they also matter for academic performance? This paper investigates the effects of digital literacy on educational outcomes by merging data from the Italian National Assessment in secondary schools with an original data set on performance tests of Internet skills for 10th grade students. Our identification strategy relies on a rich set of individual, family, school and classroom control variables that are not commonly available in previous studies. The findings indicate that, overall, Internet skills have a positive impact on academic achievement. This effect is stronger for students with low academic performance or low family background. It is also stronger for students in technical or vocational schools.

Keywords: Human capital, Academic achievement, Digital skills, Internet skills, Digital divide

JEL classification: I21, J13, J24.

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*Corresponding author. Department of Economics, Management and Statistics, University of Milan-Bicocca, Piazza dell'Ateneo Nuovo 1, 20126, Milan, Italy. E-mail: laura.pagani@unimib.it

° Department of Sociology, Catholic University of Sacred Hearth, Largo Gemelli 1, 20123, Milan, Italy. E-mail: gianluca.argentin@unicatt.it

• Department of Sociology, University of Milan-Bicocca, Piazza dell'Ateneo Nuovo 1, 20126, Milan, Italy. E-mail: marco.gui@unimib.it

◊ Department of Economics, Management and Statistics, University of Milan-Bicocca, Piazza dell'Ateneo Nuovo 1, 20126, Milan, Italy. E-mail: luca.stanca@unimib.it

1. Introduction

Recent developments in Information and Communications Technology (ICT) have transformed the way individuals learn. ICT has acquired a prominent role in the learning process, both in the educational system and at home (Meyers, Erickson, & Small, 2013). The Internet, in particular, has made available a virtually unlimited number of sources of information. As a result, the learning process increasingly requires the ability to access, locate, extract, evaluate, organize and present digital information. Since the availability of computers and the Internet is increasingly widespread in developed countries (OECD, 2007; European Commission, 2013), lack of digital skills, as opposed to lack of digital access, is becoming the key factor underlying the existing wide inequalities in how and why people use computers and the Internet (Van Deursen & Van Dijk, 2009), what has been labeled as the "second-level digital divide" (Hargittai, 2002). What matters for the learning process is no longer having access to ICT but, rather, being able to use it effectively.

Digital skills are defined in several ways by researchers in different disciplines, including media and communication, economics, sociology, education and information technology. This has led to the use of different terms, such as skills, competence, literacy, knowledge, and fluency, to refer to digital abilities (Litt, 2013).[1] Within the broad notion of digital literacy, however, it is possible to distinguish between two distinct concepts: first, a medium-related "*operational*" dimension, i.e., the ability to use computers, operating systems or browsers to navigate the web; second, a content-related "*informational*" dimension, i.e., the skills necessary to select, evaluate and re-use digital information (Van Deursen & Van Dijk, 2009). In this paper, we study the effects of the informational dimension of Internet skills on academic performance. More specifically, we focus on the skills needed to search, select and evaluate information available on the Internet.[2]

Access to digital contents plays a key role for student learning. Digital information literacy can favor a more critical use of the information available on the Internet, by reducing the likelihood of using unreliable sources. Moreover, learning through digital contents can activate specific cognitive processes, such as "trial and error" and simulations. More generally, digital literacy can be expected to enhance the ability to use computers in educationally productive ways. As a consequence, disparities in digital literacy may result in educational inequality and, in turn, amplify inequalities in the labor market. Indeed, the available evidence indicates substantial differences in digital literacy among different demographic and socio-economic groups (Van Deursen & Van Dijk, 2009).

Although there exists abundant evidence about the effects on educational outcomes of computer *ownership* (e.g., Fairlie, 2005; Schmitt & Wadsworth, 2006; Fairlie, Beltran, & Das, 2010) or computer *use* (e.g., Jackson, Eye, Witt, Zhao, & Fitzgerald, 2011; Kirschner & Karpinski, 2010; Junco, 2012; Fiorini, 2010), relatively little is known about the impacts of digital *literacy*. This paper exploits a new data set to

[1] Digital literacy generally refers to the ability to process information using digital technology in a multi-modal environment (e.g., Gilster, 1997; Rivoltella, 2008; Meyers, Erickson, & Small, 2013). More specifically, digital literacy has been defined as "the ability to read and interpret media (text, sound, images), to reproduce data and images through digital manipulation, and to evaluate and apply new knowledge gained from digital environments." (Jones-Kavalier & Flannigan, 2006).

[2] Recent studies find that informational Internet skills are particularly poor among young people (Van Deursen & Van Dijk, 2009; Gui & Argentin, 2011).

fill this gap, focusing on the effects of Internet information skills on school performance.

Our study makes a number of contributions to the existing literature. First, we rely on objective measures of both digital skills and academic performance. We measure Internet informational skills by means of a detailed performance test. Much of the existing research on digital literacy relies instead on self-reported measures, based on questionnaires or interviews (Hargittai, 2005). The validity of such measures has been questioned by several studies, owing to a misalignment between perceived and actual skills (Litt, 2013). Performance tests of digital skills have been previously implemented only in small samples, with few exceptions (Gui & Argentin, 2011). Academic performance is measured with the scores obtained by students in national standardized tests for either reading or math. To the best of our knowledge, ours is the first study of the effects of objective measures of digital skills on academic performance.

Second, by focusing on the informational dimension of digital literacy, we are able to rule out possible negative effects of digital literacy, such as time displacement effects. Operational digital skills may represent a source of distraction when ICT is used for playing games, interacting in social networks, or simply consuming online goods such as music and videos. More generally, the more time is spent using the computer for non-educational purposes, the less time is available for educational activities, such as reading or doing homework. By focusing on the informational dimension of Internet skills, we obtain a clear-cut theoretical prediction of a positive expected impact on educational outcomes.

Third, the detailed information available in our data set about student, family, classroom and school characteristics, allows us to address the potential endogeneity of digital skills. Besides providing information on a large number of observable characteristics, our data set allows us to proxy for unobservable influences at individual, family, classroom and school level, while controlling for recent and past schools outcomes as a proxy for students' unobserved ability. We also use instrumental variables in order to validate the causal interpretation of our results. We assess the effects of digital skills along the distribution of educational performance by using quantile regression. Moreover, we examine whether the effects of Internet information skills differ across types of students and schools. This allows us to test whether digital skills play a role in reducing or amplifying inequalities in education, thus providing relevant policy indications.

Overall, the results indicate that Internet information skills have a positive impact on student performance in both reading and math. Moreover, we find that the relationship between ICT skills and school performance varies widely by parental background, academic achievement and school-type. The effects are stronger for students with low socio-economic background and for low-achievers. As for school characteristics, the effects of ICT skills are stronger for students in technical and vocational schools, two tracks of the Italian schooling system associated with lower social background and lower skills (Checchi & Flabbi, 2013).

The rest of the paper is structured as follows. Section 2 provides a brief overview of the related literature. Sections 3 and 4 discuss the data and methods, respectively. Section 5 presents the econometric results. Section 6 concludes.

2. Background and related literature

The determinants of educational outcomes are commonly studied within the framework of an *education production function* that links different inputs affecting student learning to education-related outputs. Inputs include school resources, teacher quality, class size and family attributes, such as cultural background and economic resources. ICT, in particular, can be considered one of the inputs of the education production function. Output is generally measured in terms of standardized achievement test scores, but it has also been evaluated in terms of college attendance, school enrollment, graduation rates, dropout rates or labor market outcomes. Our paper is related to three main groups of studies that investigate the effect of ICTs on learning.

A first group of studies has focused on the digital divide in terms of physical access, thus exploring the role played by computer *ownership* for the learning process. Theoretically, there is no clear-cut prediction about the effect of computer ownership on student performance. On the one hand, home computers can be useful for learning in several disciplines, completing school assignments and increasing the returns to computer use in the classroom. On the other hand, the more time is spent using the computer, the less time is available for other educational activities, such as reading or doing homework. Computers may provide a distraction to children when they are used for playing games, downloading music and videos or for participating in social networks. These time displacement effects may contribute to lower academic achievement. In addition, access to the Internet may expose students to the risk of finding and using information from unreliable sources.

Among early studies, Attewell and Battle (1999) study the effect of home computers on school performance using the US 1988 National Educational Longitudinal Study. Their findings indicate that school performance among eighth graders is positively related to computer ownership. Fairlie (2005) uses the Computer and Internet Use Supplement to the 2001 US Current Population Survey to explore whether access to home computers increases the likelihood of school enrollment among teenagers who have not graduated from high school. Controlling for several family characteristics, the analysis indicates a significantly higher probability of school enrollment for students owning a home computer. Schmitt and Wadsworth (2006) find a positive relationship between home computers and school performance using data from the British Household Panel Survey between 1991 and 2001. Fuchs and Woessmann (2004), on the other hand, using the international student-level Programme for International Student Achievement database, find a negative relationship between computer ownership and math and reading test scores.

More recent studies exploit alternative identification strategies to address the potential endogeneity of computer ownership and, in particular, the possibility that more educationally motivated students (and their families) are more likely to purchase computers. Fairlie, Beltran, & Das, (2010) use two US panel data sets, the 2000–2003 CPS Computer and Internet Use Supplements matched to the CPS basic monthly files and the National Longitudinal Survey of Youth 1997. They find that home computers have a strong positive effect on high school graduation and other educational outcomes. Malamud and Pop-Eleches (2011) use a regression discontinuity design to assess the effects of home computers on child and adolescent outcomes by exploiting a voucher program in Romania. The results indicate that home computers have mixed effects on the development of human capital. Children who won a voucher to purchase a computer have significantly lower school grades but show improved computer skills. There is also some evidence that winning a voucher increases cognitive skills, but there is no effect on non-cognitive skills. Fairlie and London (2012) conduct a field experiment involving the random provision of free computers to low-income community college students for home use. The findings, based on 286 students receiving financial aid at a large community college in Northern California, provide some evidence that the treatment group achieved better educational outcomes than the control group. The estimated effects, however, are not sizeable and smaller than non-experimental estimates.

A second group of studies has explored the effect of ICT *use* on educational outcomes. The expected outcome of ICT use on the learning process can be either positive, for instance through the use of educational software, or negative, especially in the case of misuse and overuse, which may lead to physical and psychological problems. Kubey, Lavin & Barrows (2001) examine the academic consequences of heavy recreational use of the Internet by college students, finding that it is negatively related to academic performance. Fiorini (2010) uses data from the Longitudinal Study of Australian Children (LSAC) to explore the effect of using a home computer on children development. The results indicate that computer time has a positive effect on cognitive skills, while the evidence is mixed for non-cognitive skills, the effect depending on the score and the age of the children. Jackson, Eye, Biocca, Gretchen, Zhao, & Fitzgerald (2006) use longitudinal data for low-income youth with continuous and automatic recording of Internet use over 16 months. The findings indicate a positive relationship between Internet use and academic performance: youth who use the Internet more obtain higher scores on standardized tests of reading achievement and higher grade point averages than those who used the Internet less.[3] Biagi & Loi (2013), using PISA 2009 data, find that the relationship between the frequency of different types of Internet activities and reading or math literacy is generally negative in most countries, except – quite unexpectedly – for gaming. Algan & Fortin (2015) find that everyday computer gaming has neutral or positive effects for boys, and generally negative effects for girls.

Jackson, Eye, Witt, Zhao, & Fitzgerald (2011) examine the effects of Internet use on children's academic performance, finding that more Internet use is associated with better reading skills, but only for youth with initially low reading skills. Akhter (2013) studies the relationship between Internet addiction and academic performance among university undergraduates, finding that Internet addiction is negatively and significantly related to academic performance among university undergraduates. Usman, Alavi & Syed (2014) analyze the correlation between Internet addiction and academic performance among foreign undergraduate students in Malaysia. Their results indicate that there is no significant difference in academic performance depending on the amount of Internet use.

Given the widespread use of social networks by college students, several studies investigated more specifically how Facebook use relates to academic performance. Kirschner & Karpinski (2010) study Facebook use and its relation to self-reported Grade Point Average (GPA) or hours spent studying per week. Their results show that Facebook users report lower GPAs and spend fewer hours per week studying than non-users. Junco (2012) explores a sample of college students to examine the relationship among multiple measures of frequency of Facebook use, participation in Facebook activities, and time spent preparing for class and overall GPA.[4] The findings indicate that time spent on Facebook is significantly negatively related to overall GPA, while only weakly related to time spent preparing for class. Interestingly, use of

[3] Jackson (2008) focuses on the social and psychological effects of Internet use rather than its cognitive effects.

[4] See also Junco & Cotten (2012) for the effects of multitasking on academic performance.

Facebook for collecting and sharing information is positively related to the outcome variables, while a negative relationship is found for Facebook use for socializing.

A third, relatively smaller group of studies, generally outside economics, provides evidence about the effects of *digital literacy* on educational outcomes.[5] Amiri (2009) studies the effects of computer availability and digital literacy on children academic performance. The findings, based on the Make It-Take It After-School (MITIAS) case study, indicate that digital literacy has a positive effect on academic performance and participation. Leung & Lee (2012) study the relationship between Internet literacy and academic performance using survey data for 718 children and adolescents in Hong Kong. Overall, their results indicate that adolescents who have higher informational digital literacy (i.e., who can locate, browse, and access different information sources and who are knowledgeable about the context under which the information was created) perform better both in overall grades and in academic competence. Lopez-Islas (2013) studies the relationship between digital literacy and academic performance in an online learning high school program for students from underprivileged groups. The study finds that better ICT access conditions have a positive effect on digital skills and, in turn, on academic performance, by increasing the use of Internet for social and entertainment purposes, which in turn leads to more use of the learning platform software and to better digital and academic skills. These skills, in turn, have a positive effect on academic performance.

Overall, the available evidence about the effects of digital literacy on educational outcomes is not only relatively limited, but also methodologically weak. Previous results are generally based on subjective measures of digital skills and small sample sizes, while lacking detailed information about control variables and moderating factors. The main contribution of our paper is to provide evidence on the effect of digital skills on academic achievement, using an objective measure of digital skills based on a purpose-built performance test.

3. Data

Our analysis is based on a data set obtained by merging information from two sources. The first source is a survey conducted by the authors on a sample of students randomly selected from all second-year upper secondary school classes in Lombardy, the largest Italian region in the Northern part of the country. The two-stage sample (schools and classes), stratified by school type and geographical position, is representative of high school students in the Lombardy region. The survey, carried out in April 2012, covers 2,025 students from 100 classrooms in 51 different schools.

The questionnaire includes information about socio-demographic characteristics of students, such as gender, age, citizenship, parental occupation and education level. A sub-set of items provides information about recent and past academic performance and extra-curricular activities. The survey provides an in-depth description of how young people use digital media, with detailed information on ownership and use of digital devices, frequency and type of use of the Internet, and presence of digital devices and computer labs in the school. Finally, the key part of the survey provides detailed

[5] Among related studies, Eshet-Alkali & Amichai-Hamburger (2004) present results from a performance-based pioneering study designed to examine the performance of users of different age groups in tasks that require the use of different types of digital literacy skills.

objective information about the digital skills of students, measured through an in-depth standardized test. The test has been developed on the basis of a previous assessment (Gui & Argentin, 2011), which represents one of the few tools available in the literature for large-scale digital skills assessments on young people (see Hargittai & Hsieh, 2010; Litt, 2013). With respect to the previous version of the test, the one we use in this paper has been modified in two respects: 1) existing items have been updated based on recent developments in web environments; 2) the test is focused uniquely on the informational dimension of Internet skills, such as the ability to assess the reliability of web pages' content or to correctly identify sources and risks related to the use of the Internet. Many studies have found that this domain of digital competence is the most inadequate and unequally distributed among youth (Livingstone, 2003; van Deursen & van Dijk, 2009; Calvani, Fini, Ranieri, & Picci, 2011; Gui & Argentin, 2011).[6]

The second source of information consists of administrative data collected by the Italian national institute for the evaluation of the school system (INVALSI). A national assessment based on standardized tests for math and reading is administered yearly to the entire student population at various school-levels.[7] In our analysis, we consider tests administered to 10th grade pupils at the end of 2011/2012 school year, the same school year as for the performance test of Internet informational skills. The national assessment is also complemented with a student questionnaire that provides additional individual-level control variables. Standardized test scores for math and reading, the main subjects in the Italian school system, are our key indicators of academic performance and they are used as dependent variables in our analysis.

The two data sets described above were merged by matching records at individual level. Due to randomly distributed failures in the matching procedure, our final sample contains 1,466 students with reading test score and 1,443 students with math test score.[8] Both Internet skills and reading/math test scores have been standardized and range between 0 and 100. Table 1 presents summary statistics for the whole sample (a complete description of the variables is in Table A1). The average reading score is 77.8, about 20 points higher than math score. The average digital skills score is 67.3. The sample is balanced by gender. The majority of students (53%) are from *Liceo* high school (the academic track of upper secondary Italian system), 34% from technical schools and the remaining 14% from vocational schools. A student spends on average three hours per day on the Internet and his/her family owns around seven digital devices. The correlation between the digital skills score and the reading or math score is 0.37 and 0.38, respectively.

TABLE 1

[6] The tool was pre-tested in five classrooms in the Milan area. The final version of the test consists of 32 open-ended or closed-ended questions. Students were asked to evaluate the content of actual web pages, to analyze website addresses and browsers' search results, and to demonstrate their knowledge of the working logic of websites popular among youths, such as Facebook, YouTube, Yahoo Answers and Wikipedia. The survey was carried out with Computer-assisted web interviewing (CAWI), using the *LimeSurvey* open source application. A researcher was present during the entire duration of the test, in order to avoid cheating among students or from the Web and to provide solutions to technical problems.

[7] National INVALSI tests were introduced in Italian schools in 2008, with the purpose of evaluating school productivity by using standardized tests in Reading and math.

[8] We used the so-called SIDI code, used by INVALSI to identify each student, to match the two data set. However, in some of the questionnaires data needed to anonymously obtain the codes from schools were randomly missing.

4. Methods

A key methodological issue in our analysis is the potential endogeneity of students' digital skills, which may lead to inconsistent estimates of the effect of digital skills on academic achievement. There are several sources of endogeneity possibly undermining the casual interpretation of our results.

First, endogeneity may arise from unobserved heterogeneity at the individual level, as digital skills and academic performance may be jointly determined by unobserved individual characteristics. For example, Internet skills and academic performance might be positively affected by the unobserved ability or educational motivation of the students. In this case, OLS estimation would likely overstate the effect of digital literacy.

Second, at the family level, students with more educated parents or with parents in higher paying jobs will tend both to perform better at school and to have more financial resources to buy hardware (such as pc or tablets) and educational software that favor the acquisition of digital skills. Parents in high-skill jobs requiring more digital competences can teach their children how to use computers and they are also more likely to guide their children in the acquisition of academic abilities. Moreover, we cannot rule out the possibility that other unobservable family characteristics are related to both digital and academic skills: more educationally motivated families are more likely to buy computers and educational software and to guide the use of computers of their children. On the other hand, it is also possible that lower parental motivation is related to higher availability of computers as substitutes for other more pro-educational and expensive activities with children. Overall, whatever the direction of the bias, the effect of these factors may invalidate a causal interpretation of the relationship between digital skills on academic achievement.

Third, at the school level, characteristics such as higher financial resources or more motivated principals or teaching staff may be related to more resources invested in the acquisition of digital devices (such as tablets, computers or multimedia interactive whiteboards). A more favorable learning context could enhance both students' acquisition of digital skills and academic performance. In addition, at the classroom level, unobserved teacher and peer effects might lead to biased estimation results.

In view of all this, identifying the causal effect of digital skills on academic performance is not an easy task. We address the potential endogeneity of digital skills by exploiting the wide set of control variables available in our data set. More specifically, our empirical approach is based on regressing academic achievement, as measured by the math and reading national test score, on digital skills, as measured by Internet informational performance tests, while controlling for observed characteristics at individual, family, classroom and school level. This solution is clearly a second best compared to randomization or other counterfactual techniques, but we can rely on an unusually large set of control variables, since we use two merged student questionnaires. Our estimates are thus more informative than those in previous studies estimating the impact of digital skills on student performance.

More specifically, in order to take into account the possible effect of individual unobserved heterogeneity, we include among regressors indicators of students' past academic outcomes that proxy for students' unobserved ability. Italian students at the age of thirteen, at the end of the lower secondary school (two years before the survey), take a final examination and obtain a grade in a range from six to ten. Importantly, the examination final grade is based also on students' performance in a national standardized test administered during the final examination together with other tests. In addition, we include among the regressors a dummy variable for those who have failed a school year in the past.[9]

It is possible, however, that a change in individual ability had taken place after the end of the lower secondary school. In the Italian school system, a report card is issued by the school to the student's parents twice yearly. In order to control for variation in individual ability after the end of the lower secondary school, we include among the controls also the (self-reported) grades obtained by students at the end of the first term, which in Italian secondary school is January 31. Given that the national test is administered some months later (in May), we believe that school grades may provide a good additional proxy of individual unobserved ability. The data set contains information on grades obtained in math, reading, foreign language and science. We estimate two different specifications including different grades as controls. The first is the mark obtained averaging all the subjects' grades except the outcome subject (math or reading); the second specification includes the grade obtained in the most similar subject to the outcome subject (i.e., science when the outcome is math and foreign language when the outcome is reading). This variable is intended to control for unobservable subject-specific heterogeneity, namely scientific vs. humanistic aptitude.

The survey also contains information about students' self-perceived performance: they are asked whether they think they are among the best/worst students in the class, above/below the average level or around the average level. Moreover, the data set provides detailed information about extracurricular activities of students, such as sport activities, which can further help to capture individual heterogeneity.[10] Another important proxy for educational motivation is obtained from a specific question eliciting information about the educational goals of students. These are obtained by asking what is the highest educational level that students think to attain in the future, distinguishing between compulsory education (end school at 15 years old), three-year lower secondary school, five-year upper secondary school, three-year university degree and five-year university degree (master).

The INVALSI questionnaire contains two additional sets of variables that we use to control for conscientiousness and neuroticism, two important personality traits that are included in the big five aspects of personality. The first question is as follows: "When you are studying, how frequently do you do the following things: 1) give up or do only the easiest parts when a homework is difficult; 2) work hard in order to obtain good marks even when you don't like the subject; 3) finish your homework, also when it is boring." We use the answers to these questions to create a dummy variable ("conscientiousness"), which takes value 1 when the student answer never/seldom to the first statement and often/always to the second and third statements. An additional set of questions regards students' attitude towards the national INVALSI test. Students are asked to indicate the extent to which they agree with the following statements (choosing among strongly/moderately/a little/not at all) 1) I was worried about the test before doing it; 2) I was so nervous that I was not able to answer; 3) I had the feeling of doing

9 In the Italian school system, students must obtain an assessment of 6 out of 10 in each subject in order to be admitted to the next year, otherwise they have to repeat their class.

10 Involvement in extra-curricular activities is an indicator of teamwork ability, self-confidence, and the ability to succeed in competitive situations. Controlling for this variable helps isolating important self-selection factors such as ability, background, and general motivation (Lipscomb, 2007).

bad while I was answering. This results in a dummy variable ("neuroticism") taking value 1 when the student answers to agree strongly/moderately to all three statements. It should partly capture student's neuroticism, at least during the test administration. Finally, we also include a variable measuring the number of hours that students spend navigating on the web.

As regards the family level, the detailed data available in the survey allows us to control for many household-background characteristics. For both the mother and the father, we control for education level and occupation: better educated parents are more aware of the most educational Internet usage and they will likely transmit it to their children by guiding computer use. Moreover, education and occupation may be a proxy for income and influence the number and kind of digital devices available at home through a budget effect. Another indicator of family background is the number of books in the household (Schütz, Ursprung, & Woessmann, 2008). The survey contains a question asking: "how many books are there in your house", with five possible answers (0 to 10, 11 to 25, 26 to 100, 101 to 200 and more than 200). This variable is expected to account for a critical aspect of family heterogeneity related to unobservable family educational motivation. To further account for potential endogeneity at the family level we include two variables related to the educational environment describing whether in the house there is a quiet place to study and whether the student has an own bedroom. Finally, we include a variable describing the number of digital devices owned by the family (notebook, desktop, tablet, eBook reader, video game console, smartphone, pay television, wireless connection, blue-ray player, mp3 player and printer).

There might be confounding factors at the school (and classroom) level originating from endogenous sorting of students. First, we try to separate out any true digital skills effect from those simply correlated with schools characteristics, by controlling for school type. In Italy there are three types of upper secondary schools, divided into further specializations: the *Liceo*, (mostly theoretical, with specialization in humanities, science and art), technical institutes (that offer theoretical education and a specialization in a specific field of studies such as economy or technology) and vocational schools, oriented mostly towards practical subjects. Second, we include a dummy for private schools and a dummy for schools located in larger towns (provincial capitals). Finally, the specific Italian institutional setting, prohibiting class choice, helps us circumventing potential non-random sorting of students to classrooms because actual class groupings is random. Moreover, account for unobservable factors at the classroom level by estimating specifications that include classroom fixed-effects.

5. Results

This section presents the results of the empirical analysis of the relationship between digital skills and academic achievement. We start by considering OLS estimation results for the overall sample. We then focus on differences across the distribution of educational outcomes and by sub-sample. Finally, we present IV estimation results to validate the causal interpretation of our OLS estimates.

5.1 Overall sample

Tables 2 and 3 report OLS estimation results for the overall sample, using either math or reading score as a dependent variable. We consider several alternative specifications. In all models, standard errors are clustered by classroom. Column (1) reports the results obtained when controlling only for a small set of individual characteristics (gender, citizenship and presence of siblings). In column (2) we consider a larger set of control variables, aimed at better capturing individual unobserved heterogeneity: the average grade achieved at the end of the first semester in all subjects excluding the specific subject under investigation (math or reading), the self-perceived evaluation of students' own general performance, an indicator for whether the student has never failed a school year in the past, the grade obtained in the final examination of lower secondary school, a set of dummy variables for extra-curricular activities (sport, social and educational), a variable measuring students' educational goals and motivation, two variables describing personality traits (conscientiousness and neuroticism), and the number of hours spent daily on the Internet.[11] In column (3) we add measures of family inputs. Column (4) reports estimates obtained by also including school-level controls and classroom fixed-effects. As a robustness check, the last column of Tables 2 and 3 displays results obtained by considering an alternative measure of students' achievement in the first semester of the same school year. More specifically, we replace the average grade with the grade achieved in the subject more closely related to the one under investigation, i.e., science for math, and foreign languages for reading. We expect this variable to capture subject-specific heterogeneity, namely scientific vs. humanistic ability.

The results for math test score, reported in Table 2, indicate that the relationship between digital skills and academic achievement is positive and strongly significant. In column (1), the estimated coefficient for digital skills indicates that a one-point increase in digital literacy score is associated to a 0.53 point increase in math test score. As expected, the inclusion of control variables substantially reduces the size of the coefficient for digital skills, from 0.53 in column (1) to 0.16 in the full specification in columns (4) and (5). This pattern is consistent with the hypothesis that unobservable factors at individual, family and school level may simultaneously determine digital skills and academic achievement. However, the sign and statistical significance of the effect of digital skills on math performance is unaffected.

TABLE 2

The results in Table 2 also indicate a large and significant gender gap in math test score, as the coefficient for males is positive and strongly significant, with a size ranging between 6.3 and 2.3 across the different specifications. This result is consistent with the existing empirical evidence: although the origin of gender differences in math test performance is strongly debated, its existence is acknowledged in most countries (Guiso, Monte, Sapienza, & Zingales, 2008). Foreign students report significantly lower math test scores (although the size and the significance of the coefficient fall when including controls for family background and school characteristics), while self-perception and previous curricular performance are positively and strongly significantly related to math test score. As for school type, math test score is higher for students in *Liceo* and technical high school, relative to vocational schools, and in private high schools relative to public high schools.

The results for reading test score, reported in Table 3, also display a positive and significant relationship with digital skills. In column (1), the estimated coefficient for digital skills indicates that a one-point increase in digital literacy score is associated to a

[11] A detailed description of these variables is provided in section 4.2.

0.38 point increase in reading test score. Similarly to the specification for math test score, the inclusion of control variables reduces the size of the estimated coefficient for digital skills, down to 0.14 in the full specification in columns (4) and (5). The sign and significance of the relationship between digital skills and reading performance is, as above, unaffected.

TABLE 3

Focusing on control variables, there is evidence of a gender gap of opposite sign in reading test score. The coefficient for males is negative and strongly significant, with a size ranging between -3.7 and -1.7 across the different specifications.[12] Foreign students display large and significant negative differentials in reading test scores. Differently from the specification for math score, the relevant coefficient is negative and highly statistically significant also in the full specifications in columns (4) and (5), suggesting that language proficiency plays a key role in explaining the worse performance of immigrant students. As above, students' final grade at the end of lower secondary school and self-perceived school performance are positively and significantly related to reading test score. The reading test score is significantly higher for students in *Liceo* and technical high schools relative to vocational schools, whereas it is significantly lower in private relative to public high schools.

Overall, estimation results indicate that there is a positive and significant relationship between objective measures of digital skills and student performance, measured in terms of both math and reading test scores.

5.2 Quantile regression

The empirical evidence above suggests that digital skills may play an important role in improving students' outcomes. While improving students' academic performance is an important policy objective, raising the performance of the lowest achievers and, hence, favoring an increase in their productivity, may have positive effects in terms of both efficiency and equity.

The empirical literature has found that ICT availability has a stronger effect on students with lower academic performance.[13] However, there is no evidence indicating whether digital skills improve the performance of low achievers relative to other students. Our assumption is that digital skills, by allowing easier access to a broad variety of learning tools, can provide more motivation to learn for low achievers than for high-performing students. The ability in using the Internet may represent an alternative source of opportunities that becomes particularly important when other, more traditional, sources are not effective in providing capital-enhancing experiences. Hence, we expect that the potential gains of digital skills are larger for low achievers than for those whose academic performance is already high.

In order to check for differences in the impact of digital skills in different parts of the academic achievement distribution, we use quantile regression analysis. Figure 1 displays coefficients' of digital skills for different deciles of the academic achievement

[12] Also this result is in line with previous empirical literature showing that generally girls perform better than boys in reading. See Guiso, Monte, Sapienza, & Zingales (2008).

[13] Checchi, Rettore & Girardi (2015) present a counterfactual evaluation of the effect of ICT resources at school on student achievements. They find a positive impact of the program on reading score but only in the bottom tail of the distribution, while the remaining part of the distribution is virtually unaffected.

variable (for both math, panel A, and reading, panel B). In the case of math, a U-shaped curve is observed: the effect is stronger both for lowest and highest achievers, leaving behind those in the middle deciles. In the case of reading, instead, the impact of digital skills decreases monotonically along the achievement distribution: the effect of ICT ability is stronger for students performing worse. The latter result confirms our hypothesis that the effect of digital skills on academic outcomes is higher for low performers. The situation is different when considering math performance. While we observe a stronger effect at lower deciles, similarly to the case of reading, in this case the curve climbs up for higher deciles. A possibility is that those who are good in math and highly digitally skilled can better exploit the web to develop online subject-specific interests that further increase their skills in mathematics. High achievers could also be experiencing an advanced use of the Internet for which digital skills are more necessary (the use of specific software or communities).

FIGURE 1

5.3 Heterogeneous effects

Academic research in media sociology has highlighted substantial differences among individuals in the amount of time devoted to ICT and, most importantly, in the type of ICT use. In this section, we examine heterogeneity in the effects of digital skills on school performance. To this aim, we examine whether the specifications described above for math and reading test scores differ across sub-samples of students. We consider three kinds of heterogeneity. The first regards students' characteristics (gender and type of Internet use). The second dimension of heterogeneity is at the family level (parental educational level and cultural background). Third, we consider heterogeneity at the school level (school type and digital equipment of the school).

5.3.1 Student characteristics

Focusing on gender, relevant differences have been identified concerning the approach with which males and females use the Internet. Although young females use the web as frequently as their male counterparts, gender has been shown to influence the level of self-perceived skills (Liff & Shepherd, 2004; Gui, 2007; Hargittai & Shafer, 2006) and knowledge of web-related terms (Hargittai & Hinnant, 2008; Gui & Argentin, 2011).[14] Differences between genders have also emerged when considering the ability to exploit the web for learning, as the relationship between the frequency of students' use of computers and learning performance is different between boys and girls.[15]

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[14] However, research comparing men and women in their ability to solve actual tasks online does not show substantial differences (Hargittai, 2002; Hargittai & Shafer, 2006; van Deursen & van Dijk, 2011). Malamud & Pop-Eleches (2011) find that girls spend less time using computers and have lower computer skills.

[15] Regarding print reading, mathematics and science, among boys moderate users perform better than rare and intensive users, and rare and intensive users perform at around the same levels; instead, among girls, the relationship is negatively linear with a slight curve, meaning that rare users achieve slightly lower scores than moderate users, but they perform much better than intensive users. With respect to the new dimension of "digital reading performance", male intensive users tend to perform better than rare users, while among girls intensive users tend to perform at around the same level as rare users. Also, the negative association found between the use of ICT at school and digital reading performance is significantly weaker for males.

These results seem to suggest that males tend to gain more than females in learning from Internet use. Therefore, we expect the relationship between digital skills and academic performance to be stronger for males than for females. The results in Table 4 indicate that the relationship between ICT skills and math test score is stronger for males than for females (0.217 and 0.110, respectively) although the difference is not statistically significant ($p = 0.167$). For the reading test score the difference between the male and female coefficients is small and not statistically significant ($p = 0.895$).

TABLE 4

Next, we turn to heterogeneous effects in relation to students' type of Internet use. The literature clearly identifies informative use of the web as the main "human capital enhancing" practice people carry out on the Internet (see Bonfadelli, 2002; Hargittai, 2008; Van Dijk, 2005; Zillien & Hargittai, 2009). This means that searching for information is linked to socio-economic advancement more than other behaviours. Therefore, we expect that those who use the Internet for this kind of online activity to have more opportunities to exploit their digital skills for obtaining knowledge that is valued in the school system. In order to identify students using the Internet for informative purposes, we average the answers provided to four questions of the survey. These questions ask students how frequently (daily, weekly, monthly, more rarely, never) they: read news on newspapers, webpages or blogs; look for research material regarding a specific topic; use the Internet for resolving doubts about topics discussed in the classroom; use the Internet for looking for information that cannot be found in textbooks. We split the sample between students doing these activities on average weekly or daily and those doing them monthly or less frequently. Estimation results, reported in Table 4, indicate that the impact of digital skills is stronger for students making a more frequent informative use of the Internet. However, the difference in the effects of digital skills between the two groups is not statistically significant.

5.3.2 Family characteristics

We consider two key dimensions of family background: parental education and family cultural level, as measured by the number of bookshelves in the house. There is abundant evidence indicating that higher levels of parents' education are associated to a wider range of ICT uses and to more "capital enhancing" activities online (Bonfadelli, 2002; Hargittai & Hinnant, 2008; Hargittai, 2010), a larger number of activities carried out on the web (Livingstone & Helsper, 2007) and a higher level of digital skills (Hargittai, 2002; Eshet-Alkalai & Amichai-Hamburger, 2004; Van Deursen & Van Dijk, 2009). These differences in skills and range of uses of the Internet have been found also among youngsters (Livingstone & Helsper, 2007; Hargittai, 2010; Gui & Argentin, 2011). However, several studies have demonstrated that using the Internet for schoolwork does not have different impacts on students' learning outcomes depending on their social background (Thiessen & Looker, 2007; Gui, Micheli, & Fiore, 2014).

Our hypothesis is that an increase in digital skills can be of particular help for students who do not have significant cultural stimuli from their family and social context, because digital skills can act as a substitute for family background when the latter is poor. Given that family background is a good predictor of students' educational performance, detecting a stronger effect on pupils with lower background would be relevant, as it would suggest using ICT as a complementary pedagogical tool for students from poor background facing difficulties at school.

Empirically, we define high parental educational background as cases where at least one of the parents has tertiary education level, and low educational background when none of the parents has tertiary education level. As shown in Table 5, the coefficient for digital skills is large and significant for students with a low parental educational background for both math and reading. When parents' education is high, in the case of math we do not find a significant coefficient for ICT score, while the coefficient for reading is significant at the 10% level but much smaller in size as compared to the case of high parental educational background.

TABLE 5

Next, we consider the number of books in the students' home as a proxy for overall educational, social, and economic parental background. Books at home are the single most important predictor of students' performance in most countries (Woessmann, 2003, 2008).[16] They are considered the catch-all measure used to proxy for parental commitment to education. The results for sub-samples based on a threshold of one hundred books at home, reported in the last two columns of Table 5, indicate that the effects of ICT skills are stronger for students with lower parental background for reading but not for math. In the case of reading, the effect of ICT skills is stronger for low number of bookshelves (0.175) than for high number (0.094), and the difference is statistically significant (p-value 0.043). In the case of math, the effect of ICT skills is similar in the two sub-samples (0.154 and 0.167, respectively), and the difference is not statistically significant (p-value 0.904).

Overall, these results suggest that ICT ability might act as a substitute for poor family background, facilitating the acquisition of academic ability, and in particular reading skills, for students with lower educational and cultural family background. This result is consistent with the findings in Checchi, Rettore, & Girardi (2015), who show that the causal effect of school ICT resources is confined to children of less educated parents.

5.3.3 School characteristics

The Italian secondary school system comprises three main types of high schools: *Liceo* high schools, specifically designed to prepare students for tertiary education; technical high schools, giving students the possibility to pursue either an occupation or additional education; vocational schools, preparing students for an occupation upon graduation.[17] Within each school type, socio-economic backgrounds and learning levels tend to be homogeneous and different from the other types along a hierarchy, with *Liceo* at the top and vocational courses at the bottom (Schizzerotto & Barone, 2006). *Liceo* high schools have a strong tradition based on theoretical analysis, mostly focused on humanistic studies, with more traditional teaching practice. On the contrary, technical and vocational schools are more open to innovation, as they tend to follow the markets for

[16] Obviously, this does not mean that the number of books in the home are causally related to students' academic performance. Rather, they proxy systematic differences in socio-economics background that are causally related to achievement.

[17] See also Section 4.

which they train their students. Therefore, we expect the capability to positively convert digital skills into learning outcomes to be higher for students attending technical or vocational schools.

Table 6 presents results for heterogeneity at the school level. The findings indicate large differences in the relation between ICT score and academic performance: the estimate for ICT score is lower for students of *Liceo* high schools, relative to technical and vocational schools for both reading and math. The difference is largest between students of *Liceo* and vocational schools for reading (digital skills coefficients are, respectively, 0.092 and 0.219, p-value for the difference 0.008).[18]

TABLE 6

As regards the digital environment of the school, the presence of multimedia interactive whiteboards (IWB) usually implies an increase in the creation and use of digital resources by the students. We thus expect that the presence of an IWB makes digital skills more likely to enhance learning outcomes. Estimation results obtained by splitting the sample according to the presence of the IWB in the classroom show that the relationship between ICT score and academic performance is stronger for students equipped with IWB during lessons. This result suggests that digital skills might favour learning more in digital environments, indicating potential complementarities between students' ICT ability and school's digital equipment. However, although the coefficient of digital skills is higher in both math and reading equations for students in schools equipped with IWB than for students without IWB, this difference is not statistically significant ($p = 0.762$ and $p = 0.451$, respectively, for math and reading).

5.4 Endogeneity

The results presented above provide robust evidence of a positive relationship between digital skills and academic achievement. However, although we control for a very rich set of individual, family and school characteristics, we cannot rule out the possibility that the error term is related to the regressor, due to unobserved heterogeneity or simultaneity. Given the cross-sectional nature of the data set, there is no within-student variation allowing identification. In order to assess the causal interpretation of our results, we thus use an instrumental variable (IV) estimator. The IV approach provides a consistent estimator under the assumption of instrument validity, i.e., that the instruments are correlated with the endogenous regressor (digital skills) but not with the error term (i.e., the dependent variable).

The survey we are using provides detailed information about the help that parents give to their children in doing some specific web-related activities. Specifically, students are asked whether their parents help them to discover useful websites for school purposes and whether their parents stimulate them to explore the web. We use this information for obtaining the exclusion restrictions that are necessary to estimate the IV model. Our identifying assumption is that parents' help in this kind of activities is related to the student's digital skills. On the other hand, web-related parents' help should not be correlated with academic performance after controlling for individual,

[18] We estimated the model also distinguishing only between *liceo* students and other schools (technical and vocational) students. The coefficients of ICT ability is lower for *liceo* students for both math and reading and the difference is statistically significant in both cases.

family and school characteristics.

Table 7 presents two-stage least squares estimation results. First stage results, not reported in the table, indicate that both instruments are strongly statistically significant. Second stage results confirm that the relationship between digital skills and academic achievement is positive and significant for both math (0.546) and reading (0.368). The fact that IV estimates of the effect of digital skills are indeed larger than OLS estimates, is consistent with attenuation bias caused by measurement error or with larger standard errors in the presence of weak instruments. Given that the model has two instruments and one endogenous regressor, we can test whether the instruments are uncorrelated with the error term with a test of over-identifying restrictions. Test results indicate that instruments validity is not be rejected in both the math and the reading equation (p-value of the Sargan test equal to 0.3179 and 0.5009 for math and reading, respectively).

TABLE 7

6. Conclusions

As the availability of computers and the Internet is increasingly widespread in developed countries, ability, rather than access, represents the crucial determinant of digital inequality. So far, the literature has mainly focused on the determinants of digital competence, while there is little evidence on its effect on academic outcomes.

In this paper, we used an unusually rich database, obtained by merging two student-level data sets, to study the effects of digital literacy on educational performance. We focus on *informational* digital skills, namely a content-related dimension of Internet ability necessary to select, evaluate and re-use digital information. The existing evidence indicates that this dimension of digital skills is particularly poor among the young (Van Deursen & Van Dijk, 2009; Gui & Argentin, 2011). Moreover, previous research indicates that there are substantial differences in digital literacy among different demographic and socio-economic groups (Van Deursen & Van Dijk, 2009).

We measure academic performance using standardized test scores in both math and reading. Digital skills are measured by means of an in-depth standardized test obtained through an *ad hoc* survey. The very rich set of control variables allows us to take into account unobserved heterogeneity at individual, family and school level. Our results indicate that informational digital skills have a positive and significant effect on academic performance. A one-point increase in digital literacy test score is associated to a 0.17 point increase in math test score and to a 0.14 point increase in reading test score. IV estimation results support the causal interpretation of the estimated relationship.

Interestingly, we find that the effect of digital skills varies by student characteristics. In particular, quantile regression results indicate that students with lower reading academic performance are those who benefit more from digital literacy, while for math we find a U-shape relationship between digital skills and student achievement. We also find that the effect of ICT literacy is stronger for students with a lower socio-economic background, suggesting that digital skills might act as a substitute for family background, by facilitating the acquisition of academic ability. Stronger effects of digital literacy for students with lower school achievement and socio-economic background suggest that programs aimed at increasing internet information skills among the youth can play an important role in reducing educational inequality and, in turn, lowering inequalities in the labor market. Further research will shed light on the specific mechanisms underlying the effects of digital literacy on academic performance.

Appendix

TABLE A1

References

Akhter, N. (2013). Relationship between Internet Addiction and Academic Performance among University Undergraduates. *Educational Research and Reviews, 8*(19), 1793-1796.

Algan, Y., & Fortin, N. (2015). Computer Gaming and Test Scores: Cross-Country Gender Differences among Teenagers. *Working paper*. The University of British Columbia.

Amiri, S. (2009). The effects of information and communication technology on at risk children of low economic status: Make It-Take It After-School Case Study. *International Journal of Education and Development using Information and Communication Technology, 5*(3), 141-147.

Attewell, P., & Battle, J. (1999). Home computers and school performance. *The Information Society, 15*(1), 1–10.

Biagi, F., & Loi, M. (2013). Measuring ICT Use and Learning Outcomes: evidence from recent econometric studies. *European Journal of Education, 48*(1), 28-42.

Bonfadelli, H. (2002). The Internet and knowledge gaps: A theoretical and empirical investigation. *European Journal of Communication, 17*(1), 65-84.

Calvani, A., Fini, A., Ranieri, M., & Picci, P. (2012). Are young generations in secondary school digitally competent? A study on Italian teenagers. *Computers and Education, 58*(2), 797-807.

Checchi, D., & Flabbi, L. (2013). Intergenerational Mobility and Schooling Decisions in Germany and Italy: The Impact of Secondary School Tracks. *Rivista di Politica Economica, 3*, 7-57.

Checchi, D., Rettore, E., & Girardi, S. (2015). IC Technology and Learning: An Impact Evaluation of Cl@ssi2.0. IZA Discussion Paper No. 8986.

DiMaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2004). Digital inequality: From unequal access to differentiated use. In K.M. Neckerman (Ed.), *Social Inequality*, (pp. 355-400). New York: Russell Sage Foundation.

Eshet-Alkali, Y., & Amicai-Hamburger, Y. (2004). Experiments in Digital Literacy. *Cyberpsychology and Behavior, 7*(4), 421-429.

European Commission (2013). *Survey of Schools: ICT in Education*. Luxembourg, Publications Office of the European Union.

Fairlie, R.W. (2005). The Effects of Home Computers on School Enrollment. *Economics of Education Review, 24*(5), 533-547.

Fairlie, D., Beltran, D., & Das, L. (2010). Home Computers and Educational Outcomes: Evidence from the NLSY97 and CPS. *Economic Inquiry, 48*(3), 771–792.

Fairlie, R.W., & London, R.A. (2012). The Effects of Home Computers on Educational Outcomes: Evidence from a Field Experiment with Community College Students. *Economic Journal*, 122(561), 727-753.

Fiorini, M. (2010). The Effect of Home Computer Use on Children’s Cognitive and Non-Cognitive Skills. *Economics of Education Review, 29*(1), 55-72.

Fuchs, T., & Woessmann, L. (2004). Computers and student learning: bivariate and multivariate evidence on the availability and use of computers at home and at school. CESIFO Working Paper No. 1321.

Gilster, P. (1997). *Digital Literacy*. New York, John Wiley.

Gui, M. (2007). Formal and substantial Internet information skills: The role of socio-demographic differences on the possession of different components of digital literacy. *First Monday*, *12*(9).

Gui, M., & Argentin, G. (2011). Digital skills of internet natives: Different forms of digital literacy in a random sample of northern Italian high school students. *New Media & Society*, *13*(6), 963-980.

Gui, M., Micheli, M., & Fiore, B. (2014). Is the Internet creating a learning gap among students? Evidence from the Italian PISA data. *Italian Journal of Sociology of Education*, *6*(1), 1-24.

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender and math. *Science, 320*(5880), 1164-1165.

Hargittai, E. (2002). Second-level digital divide: differences in people’s online skills. *First Monday, 7*(4).

Hargittai, E. (2005). Survey measures of web-oriented digital literacy. *Social Science Computer Review, 23*(3), 371–379.

Hargittai, E. (2008). The Digital Reproduction of Inequality. In D. Grusky, *Social Stratification* (pp. 936-944). Boulder, CO: Westview Press.

Hargittai, E. (2010). Digital na(t)ives? Variation in internet skills and uses among members of the “net generation”. *Sociological Inquiry*, *80*(1), 92-113.

Hargittai, E., & Hinnant, A. (2008). Digital Inequality: Differences in Young Adults' Use of the Internet. *Communication Research, 35*(5), 602-621.

Hargittai, E., & Hsieh, Y.P. (2010). Predictors and Consequences of Social Network Site Usage. *Information, Communication & Society, 13*(4), 515-536.

Hargittai, E., & Shafer, S. (2006). Differences in actual and perceived online skills: the role of gender. *Social Science Quarterly*, *87*(2), 432-448.

Jackson, L.A. (2008). Adolescents and the Internet. In P.E. Jamieson, & D. Romer, *The changing portrayal of American youth in popular media* (pp. 377-410). Oxford: Oxford University Press.

Jackson, L.A., Eye, A.V., Biocca, F., Gretchen, B., Zhao, Y., & Fitzgerald, H.E. (2006). Does home Internet use influence the academic performance of low-income children?. *Developmental Psychology, 42*(3), 429–435.

Jackson, L.A., Eye, A.V., Witt, E.A., Zhao, Y., & Fitzgerald, H.E. (2011). A longitudinal study of the effects of Internet use and videogame playing on academic performance and the roles of gender, race and income in these relationships. *Computers in Human Behavior, 27*(1), 228–239.

Jones-Kavalier, B.R., & Flannigan, S.L. (2006). Connecting the digital dots: Literacy of the 21st century. *Educause Review, 29*(2), 8-10.

Junco, R. (2012). Too much face and not enough books: The relationship between multiple indices of Facebook use and academic performance. *Computers in Human Behavior, 28*(1), 187–198.

Junco, R., & Cotten, S. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers and Education, 59*(2), 505–514.

Kirschner, P., & Karpinski, A. (2010). Facebook and academic performance. *Computers in Human Behavior 26*(6), 1237–1245.

Kubey, R., Lavin, M.J., & Barrows, J.R. (2001). Internet use and collegiate academic performance decrements: Early findings. *Journal of Communication, 51*(2), 366–382.

Leung, L., & Lee, P. (2012). Impact of Internet Literacy, Internet Addiction Symptoms, and Internet Activities on Academic Performance. *Social Science Computer Review, 30*(4), 403-418.

Liff, S., & Shepherd, A. (2004). An evolving gender digital divide?. *Oxford Internet Institute, Internet Issue Brief No. 2*.

Livingstone, S. (2003). Children's use of the internet: Reflections on the emerging research agenda. *New Media & Society*, *5*(2), 147-166.

Livingstone, S., & Helsper, E.J. (2007). Gradations in digital inclusion: Children, young people and the digital divide. *New Media & Society, 9*(4), 671-696.

Litt, E. (2013). Measuring users' internet skills: A review of past assessments and a look toward the future. *New Media & Society, 15*(4), 612-630.

Lipscomb, S. (2007). Secondary school extracurricular involvement and academic achievement: a fixed effects approach, *Economics of Education Review, 26*(4), 463–472.

Lopez Islas, J.R. (2013). Digital literacy and academic success in online education for underprivileged communities: The prep@net case. Ph.D. Dissertation, University of Texas, Austin.

Malamud, O., & Pop-Eleches, C. (2011). Home Computers Use and the Development of Human Capital. *The Quarterly Journal of Economics, 126*(2), 987–1027.

Meyers, E., Erickson, I., & Small, R. (2013). Digital literacy and informal learning environments: An introduction. *Learning, Media and Technology 38*(4), 355-367.

OECD (2007). Working party on the information economy. Broadband and ICT access and use by households and individuals. Available at: http://www.oecd.org/dataoecd/44/11/39869349.pdf

Rivoltella, P.C. (2008). *Digital literacy: Tools and methodologies for information society*. Hershey PA, IGI Publishing.

Schizzerotto, A., & Barone, C. (2006). *Sociologia dell'istruzione*. Bologna, Il Mulino.

Schmitt, J., & Wadsworth, J. (2006). Is there an impact of household computer ownership on children's educational attainment in Britain?. *Economics of Education Review, 25*(6), 659–73.

Schütz, G., Ursprung, H., & Woessmann, L. (2008). Education policy and equality of opportunity. *Kyklos*, *61*(2), 279-308.

Thiessen, V., & Looker, D. (2007). Digital divides and capital conversion: The optimal use of information and communication technology for youth reading achievement. *Information, Community & Society,* 10(2), 159-180.

Usman, N., Alavi, M., & Syed, M. (2014). Relationship between Internet Addiction and Academic Performance among Foreign Undergraduate Students. *Procedia - Social and Behavioral Sciences, 114*, 845 – 851.

Van Deursen, A., & Van Dijk, J. (2009). Using the Internet: Skill Related Problems in Users' Online Behavior. *Interacting with Computers*, *21*(5-6), 393-402.

Van Deursen, A., & Van Dijk, J. (2011). Internet skills and the digital divide. *New Media & Society*, *13*(6), 893-911.

Van Dijk, J. (2005). *The deepening divide. Inequality in the information society*. London, Sage Publications.

Woessmann, L. (2003). Schooling resources, educational institutions, and student performance: The international evidence. *Oxford Bullettin of Economics and Statistics*, *65*(2), 117–170.

Woessmann, L. (2008). How equal are educational opportunities? Family background and student achievement in Europe and the United States. *Zeitschrift fur Betriebswirtschaft 78*(1), 45–70.

Zillien, N., & Hargittai, E. (2009). Digital distinction: Status-specific Internet uses. *Social Science Quarterly*, *90*(2), 274-291.

Table 1. Summary statistics

	Mean	Std. Dev.	Min	Max
Individual characteristics				
Reading score	77.8	12.04	0.97	97.09
Math score	56.66	17.02	9.26	100
Digital test score	67.3	11.13	28.13	96.88
Male	0.47	0.5	0	1
Migrant	0.06	0.24	0	1
Presence of siblings	0.75	0.43	0	1
Score lower secondary school	2.86	1.17	1	5
Report card score (reading)	6.55	0.95	1	10
Report card score (math)	6.34	1.42	1	10
Report card score (science)	6.73	1.09	1	10
Report card score (foreign language)	6.71	1.16	1	10
Self perception	3.12	0.93	1	5
Never failed	0.85	0.36	0	1
Extracurricular actvity: sport	0.71	0.45	0	1
Extracurricular actvity: group	0.28	0.45	0	1
Extracurricular actvity: educational	0.22	0.41	0	1
Educational goals	4.66	1.35	1	6
Coscientiousness	0.43	0.5	0	1
Neuroticism	0.05	0.21	0	1
Internet hours	3.03	2.5	0	16
Family characteristics				
Nr books	3.38	1.21	1	5
Has quiet place to study	0.85	0.35	0	1
Has a own bedroom	0.62	0.48	0	1
Father manager	0.14	0.35	0	1
Father teacher	0.02	0.14	0	1
Father white collar	0.18	0.38	0	1
Father blue collar	0.31	0.46	0	1
Father business activity	0.09	0.29	0	1
Father professional	0.1	0.3	0	1
Father self employed	0.14	0.35	0	1
Father non working	0.01	0.08	0	1
Father absent	0.02	0.12	0	1
Mother manager	0.04	0.2	0	1
Mother teacher	0.1	0.3	0	1
Mother white collar	0.32	0.47	0	1
Mother blue collar	0.15	0.36	0	1
Mother business activity	0.02	0.14	0	1
Mother professional	0.06	0.24	0	1
Mother self employed	0.07	0.26	0	1
Mother housewife	0.21	0.41	0	1
Mother non working	0.01	0.11	0	1
Mother absent	0	0.07	0	1
Father education: primary	0.04	0.2	0	1
Father education: lower secondary	0.28	0.45	0	1
Father education: upper secondary	0.41	0.49	0	1
Father education: tertiary	0.22	0.41	0	1
Father education: do not know/do not answer	0.05	0.21	0	1
Mother education: primary	0.02	0.15	0	1
Mother education: lower secondary	0.24	0.43	0	1
Mother education: upper secondary	0.44	0.5	0	1
Mother education: tertiary	0.28	0.45	0	1
Mother education: do not know/do not answer	0.02	0.15	0	1
Nr digital devices	7.37	1.75	0	11
School characteristics				
Liceo high school	0.53	0.5	0	1
Technical high school	0.34	0.47	0	1
Vocational high school	0.14	0.34	0	1
Private school	0.11	0.31	0	1
School in provincial capital	0.44	0.5	0	1
Nr obs	1466			

Table 2. Estimation results, math test score

	(1)	(2)	(3)	(4)	(5)
Digital test score	0.532***	0.246***	0.235***	0.164***	0.166***
	(0.055)	(0.045)	(0.046)	(0.032)	(0.032)
Male	4.654***	6.278***	6.087***	2.541***	2.330***
	(1.305)	(1.166)	(1.150)	(0.841)	(0.811)
Migrant	-7.147***	-3.118*	-3.198*	-1.944	-2.284*
	(1.788)	(1.659)	(1.731)	(1.224)	(1.265)
Siblings	1.822**	1.711**	1.635*	0.553	0.512
	(0.908)	(0.787)	(0.822)	(0.654)	(0.648)
Mean score first semester		-0.106	-0.187	1.357**	
		(0.842)	(0.889)	(0.622)	
Score sciences					0.902**
					-0.407
Self perceived performance		0.79	0.907	2.306***	2.494***
		(0.624)	(0.598)	(0.466)	(0.428)
Never failed		4.305***	3.982***	1.864**	1.926**
		(1.399)	(1.394)	(0.905)	(0.894)
Final grade lower secondary		5.000***	4.996***	1.679***	1.854***
		(0.598)	(0.596)	(0.441)	(0.401)
Extracurricular: sport		1.367	1.131	-0.36	-0.348
		(0.946)	(0.975)	(0.726)	(0.727)
Extracurricular: group		0.833	0.431	0.328	0.259
		(1.073)	(1.021)	(0.707)	(0.687)
Extracurricular: educ.		1.068	0.526	-0.299	-0.248
		(0.937)	(0.953)	(0.659)	(0.652)
Educational goals		1.438**	1.145**	0.216	0.203
		(0.552)	(0.515)	(0.344)	(0.346)
Coscientiousness		-0.853	-1.261	-0.685	-0.689
		(0.908)	(0.883)	(0.678)	(0.679)
Neuroticism		-4.092***	-3.327**	-1.467	-1.439
		(1.236)	(1.263)	(1.273)	(1.271)
Internet hours		-0.530***	-0.436**	-0.266**	-0.245*
		(0.188)	(0.188)	(0.129)	(0.128)
Nr books			0.553	-0.118	-0.116
			(0.467)	(0.280)	(0.291)
Quiet place to study			0.619	1.348	1.235
			(1.495)	(1.287)	(1.294)
Own bedroom			0.332	-0.236	-0.179
			(1.013)	(0.838)	(0.840)
Nr digital devices			-0.583**	-0.298	-0.291
			(0.240)	(0.189)	(0.192)
Liceo high school				20.629***	20.216***
				(1.513)	(1.456)
Technical high school				33.581***	33.024***
				(1.266)	(1.224)
Private school				2.354**	2.594***
				(0.923)	(0.884)
School in provincial capital				-3.172***	-3.310***
				(0.770)	(0.778)
Constant	17.709***	10.269**	4.889	1.125	3.907
	(3.677)	(4.671)	(10.161)	(6.722)	(6.472)
CONTROL FOR					
Parents' education and occupation	NO	NO	YES	YES	YES
Classroom fixed-effect	NO	NO	NO	YES	YES
Observations	1,438	1,318	1,297	1,297	1,297
R-squared	0.18	0.383	0.417	0.717	0.718

Note: Dependent variable: math test score. Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: * 10%, ** 5%, *** 1%.

Table 3. Estimation results, reading test score

	(1)	(2)	(3)	(4)	(5)
Digital test score	0.379***	0.204***	0.186***	0.138***	0.138***
	(0.031)	(0.028)	(0.027)	(0.023)	(0.023)
Male	-3.728***	-2.243***	-2.119***	-1.670***	-1.696***
	(0.853)	(0.644)	(0.671)	(0.525)	(0.542)
Migrant	-12.236***	-9.519***	-8.781***	-6.865***	-6.729***
	(1.421)	(1.546)	(1.653)	(1.590)	(1.601)
Siblings	0.893	0.605	0.496	0.49	0.531
	(0.690)	(0.462)	(0.504)	(0.459)	(0.459)
Mean score first semester		0.312	0.639	0.786**	
		(0.446)	(0.418)	(0.373)	
Score languages					0.37
					-0.271
Self perceived performance		0.33	0.117	1.185***	1.409***
		(0.476)	(0.467)	(0.373)	(0.342)
Never failed		1.681	1.296	0.145	0.126
		(1.186)	(1.113)	(0.802)	(0.807)
Final grade lower secondary		2.946***	2.876***	1.562***	1.640***
		(0.337)	(0.347)	(0.321)	(0.314)
Extracurricular: sport		0.681	0.601	0.522	0.575
		(0.520)	(0.560)	(0.546)	(0.546)
Extracurricular: group		0.438	0.002	0.03	0.089
		(0.501)	(0.497)	(0.436)	(0.438)
Extracurricular: educ.		0.459	0.088	-0.308	-0.357
		(0.591)	(0.634)	(0.605)	(0.601)
Educational goals		1.123***	1.056***	0.055	0.086
		(0.279)	(0.249)	(0.255)	(0.255)
Coscientiousness		-0.055	-0.267	0.182	0.262
		(0.496)	(0.497)	(0.498)	(0.494)
Neuroticism		-3.254**	-2.652**	-1.067	-1.07
		(1.239)	(1.150)	(1.508)	(1.531)
Internet hours		-0.376**	-0.301*	-0.105	-0.12
		(0.161)	(0.155)	(0.109)	(0.109)
Nr books			0.993***	0.485	0.499*
			(0.321)	(0.292)	(0.291)
Quiet place to study			-0.672	-0.578	-0.495
			(0.912)	(0.956)	(0.968)
Own bedroom			-0.427	-0.228	-0.254
			(0.478)	(0.465)	(0.466)
Nr digital devices			-0.211	-0.146	-0.158
			(0.180)	(0.124)	(0.125)
Liceo high school				22.216***	22.023***
				(1.509)	(1.526)
Technical high school				26.894***	26.934***
				(1.156)	(1.175)
Private school				-8.728***	-8.581***
				(0.899)	(0.878)
School in provincial capital				-1.171**	-1.154**
				(0.520)	(0.539)
Constant	54.139***	47.832***	36.305***	35.797***	37.543***
	(2.333)	(3.231)	(6.260)	(4.472)	(4.026)
CONTROL FOR					
Parents' education and occupation	NO	NO	YES	YES	YES
Classroom fixed-effect	NO	NO	NO	YES	YES
Observations	1,466	1,318	1,297	1,297	1,297
R-squared	0.214	0.424	0.465	0.624	0.623

Note: Dependent variable: reading test score. Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: * 10%, ** 5%, *** 1%.

Table 4. Digital skills and academic performance, by student characteristics

	Gender		Informative internet use	
	Male	Female	Low	High
Math				
Digital test score	0.217***	0.110**	0.151***	0.174***
	(0.055)	(0.045)	(0.054)	(0.048)
Observations	591	706	589	708
R-squared	0.754	0.724	0.74	0.741
Reading				
Digital skills test	0.132***	0.134***	0.107***	0.173***
	(0.039)	(0.031)	(0.039)	(0.033)
Observations	591	706	589	708
R-squared	0.668	0.652	0.638	0.699

Note: Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: ** 5%, *** 1%. Control variables as in Table 2 (for math) and 3 (for reading), column 4.

Table 5. Digital skills and academic performance, by family characteristics

	Parents' education		Number of books	
	Low	High	Low	High
Math				
Digital test score	0.213***	0.065	0.154***	0.167***
	(0.042)	(0.058)	(0.046)	(0.049)
Observations	841	456	683	614
R-squared	0.714	0.749	0.725	0.737
Reading				
Digital skills test	0.157***	0.070*	0.175***	0.094***
	(0.034)	(0.039)	(0.035)	(0.029)
Observations	841	456	683	614
R-squared	0.631	0.675	0.664	0.632

Note: Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: ** 5%, *** 1%. Control variables as in Table 2 (for math) and 3 (for reading), column 4.

Table 6. Digital skills and academic performance, by school characteristics

	School type			IWB	
	Liceo	Technical	Vocational	Yes	No
Math					
Digital test score	0.107**	0.204***	0.189*	0.210***	0.177***
	(0.040)	(0.063)	(0.087)	(0.058)	(0.044)
Observations	708	396	193	391	906
R-squared	0.701	0.677	0.693	0.746	0.735
Reading					
Digital skills test	0.092***	0.126**	0.219***	0.172***	0.105***
	(0.026)	(0.046)	(0.064)	(0.048)	(0.028)
Observations	708	396	193	391	906
R-squared	0.529	0.481	0.62	0.746	0.626

Note: Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: ** 5%, *** 1%. Control variables as in Table 2 (for math) and 3 (for reading), column 4.

Table 7. IV results

VARIABLES	(1) Math	(2) Reading
Digital test score	0.546***	0.368**
	(0.196)	(0.147)
Male	1.566*	-2.241***
	(0.843)	(0.624)
Migrant	-1.707	-6.710***
	(1.367)	(1.027)
Siblings	0.582	0.514
	(0.686)	(0.515)
Final grade lower secondary	0.934*	1.102***
	(0.531)	(0.404)
Mean score first semester	1.078*	0.675*
	(0.562)	(0.374)
Self perceived performance	2.038***	1.013***
	(0.442)	(0.347)
Never failed	1.878**	0.150
	(0.907)	(0.680)
Extracurricular: sport	-0.906	0.192
	(0.736)	(0.553)
Extracurricular: group	0.332	0.033
	(0.663)	(0.497)
Extracurricular: educ.	-0.505	-0.440
	(0.715)	(0.537)
Educational goals	0.042	-0.052
	(0.321)	(0.241)
Coscientiousness	-0.476	0.305
	(0.629)	(0.472)
Neuroticism	-1.063	-0.834
	(1.356)	(1.015)
Internet hours	-0.292**	-0.120
	(0.132)	(0.099)
Nr books	-0.521	0.238
	(0.363)	(0.274)
Quiet study place	2.058*	-0.145
	(1.144)	(0.860)
Own bedroom	-0.522	-0.404
	(0.675)	(0.507)
Nr digital devices	-0.295	-0.143
	(0.184)	(0.138)
Liceo high school	16.839***	16.468***
	(3.587)	(2.689)
Technical high school	21.583***	21.164***
	(5.411)	(4.061)
Private school	10.680***	-3.601
	(3.501)	(2.627)
School in provincial capital	1.148	1.567
	(5.991)	(4.486)
Constant	-8.220	32.336***
	(10.037)	(7.612)
Observations	1,297	1,297
R-squared	0.676	0.591

Note: Robust standard errors adjusted for clustering at the classroom level in parentheses. Significance level: * 10%, ** 5%, *** 1%. Control variables as in Table 2 (for math) and 3 (for reading), column 4.

Figure 1. Quantile regressions coefficients of digital skills

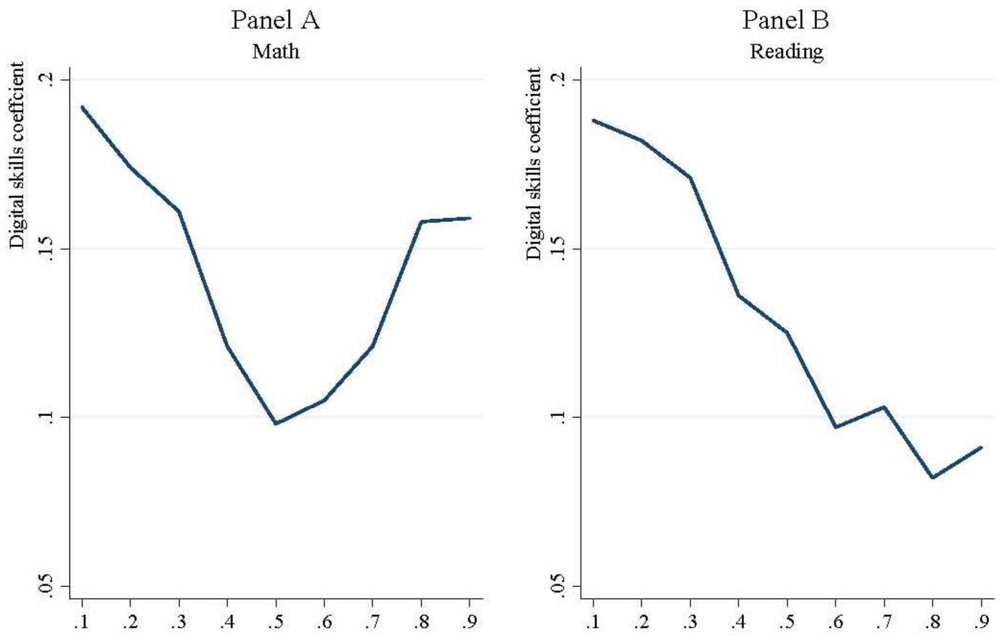

Table A1. Definition of variables

VARIABLES	*Description*
Reading score	Invalsi reading score
Math score	Invalsi math score
Digital test score	Digital skills score
Male	1 if student is male
Migrant	1 if student's citizenship is not Italian
Siblings	1 if student has siblings
Final grade lower secondary	Score at the end of the lower secondary school
Report card score (science)	Report card score (science)
Self perceived performance	School performance self perception: 1 if among the best students in the class; 2 if above class average; 3 if at the class average; 4 below the class average; 5 among the worst students in the class
Never failed	1 if the student never failed a school year
Extracurricular actvity: sport	1 if the student performs sport activities during free time
Extracurricular actvity: group	1 if the student performs group activities during free time
Extracurricular actvity: educational	1 if the student performs educational activities during free time
Educational goals	Highest target school level: 1 if compulsory education (no more years); 2 if lower vocational (1 more year); 3 if high school diploma (3 more years); 4 if lower tertiary (5 more years); 5 if degree (6 more years); 6 if master or phd (8 more years or more)
Coscientiousness	1 if the student answered never/seldom to the question: "I give up or do only the easiest parts when a homework is difficult" and if s/he answered often/always to the questions: "I work hard in order to obtain good marks even when you don’t like the subject" and "I finish your homework, also when it is boring"
Neuroticism	1 if the student answered to agree strongly/moderately with all the following statements: 1) I was worried about the test before doing it; 2) I was so nervous that I was not able to answer; 3) I had the feeling of doing bad while I was answering
Internet hours	Number of daily Internet hours
Nr books	1 if in the house there are 0 to 10 books; 2 if there are 11 to 25 books; 3 if there are 26 to 100 books; 4 if there are 101 to 200 books; 5 if there are more than 200 books
Quiet place to study	1 if student has a quiet place to study
Own bedroom	1 if student has a own bedroom
Father manager	1 if father is a manager
Father teacher	1 if father is a teacher
Father white collar	1 if father is a white collar
Father blue collar	1 if father is a blue collar
Father business activity	1 if father is an enterprenour
Father professional	1 if father is a professional worker
Father self employed	1 if father is a self employed
Father non working	1 if father is not working
Father absent	1 if father is absent
Mother manager	1 if mother is a manager
Mother teacher	1 if mother is a teacher
Mother white collar	1 if mother is a white collar
Mother blue collar	1 if mother is a blue collar
Mother business activity	1 if mother is an enterprenour
Mother professional	1 if mother is a professional worker
Mother self employed	1 if mother is a self employed
Mother housewife	1 if mother is an housewife
Mother non working	1 if mother is not working

Table A1. Definition of variables (cont'd)

VARIABLES	*Description*
Mother absent	1 the mother is absent
Father education: primary	1 father education is primary or less
Father education: lower secondary	1 father education is lowe secondary
Father education: upper secondary	1 father education is upper secondary
Father education: tertiary	1 father education is tertiary
Mother education: primary	1 mother education is primary or less
Mother education: lower secondary	1 mother education is lowe secondary
Mother education: upper secondary	1 mother education is upper secondary
Mother education: tertiary	1 mother education is tertiary
Nr digital devices	Number of digital devices in the house among: notebook, desktop, tablet, eBook reader, video game console, smartphone, pay television, wireless connection, blu-ray player, mp3 player and printer.
Liceo high school	1 if student is from liceo high school
Technical high school	1 if student is from technical high school
Vocational high school	1 if student is from vocational high school
Private school	1 if student is from a private high school
School in provincial capital	1 if student's school is located in a provincial capital