Is it the way they use it? Teacher, ICT and student achievement

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Abstract

The aim of this paper is to study the effect of ICT-related teaching practices on student achievement. We match data on standardized tests' measures of 10^{th} grade student performance with a unique student-teacher data-set containing a wide range of ICT-related variables on both ICT knowledge and ICT using teaching practices. Within-student between-subject estimates show that ICT-related teaching practices increase student performance if they help the teacher to get further material to prepare his/her lectures or if they channel the transmission of teaching material or are used to increase students awareness in ICT use. We also find a positive effect of ICT using communication-enhancing practices. Instead, a negative effect is found only for practices requiring a more active role of the students in class in using ICT.

JEL Code: I20, I21

Keywords: teacher quality, teaching practices, ICT, student performance

1. Introduction

National and local government programs for Information and Communications Technologies (ICT) in schools have been adopted in many countries in the last two decades with the aim of guaranteeing extensive access to ICT. In nearly all countries, actions within the ICT education strategies are funded mainly from the public budget. Budgets are allocated between equipment and human resources, but purchase and maintenance of equipment and facilities have often taken precedence in expenditure (Eurydice, 2011).

Major investment amounts over the past 20 years have brought ICT into nearly all schools in the most advanced OECD countries. In 2009 97% of the teachers in public elementary and secondary schools in the USA had one or more computers located in the classroom every day (93% of them with Internet access) and the ratio of students to computers in the classroom was 5.3 to 1 (Gray et al 2010). In the same year, in Europe at least 75 % of the students had the availability of one computer for up to four students, and inequality in ICT availability between schools have reduced a lot (Eurydice, 2011). The latest EU-survey on ICT in schools confirms that ICT has become more pervasive: in the 2011-12 school year, there were around twice as many computers per 100 students in secondary schools as compared with 2006. The share of schools with websites, e-mail for both teachers and students and a local area network has been steadily increasing in all levels of education (European Commission, 2013).

In view of the large public outlays for ICT in schools in many countries, there has been an increasing literature trying to identify the effect of ICT at school, for instance classroom computers, use of specific software or internet access availability, on learning. While a consensual agreement has not been reached, most studies find either little or no effect. As regards the effect of ICT funding and computer availability at school, Machin et al (2007), exploiting a change in the rules governing ICT funding across different school districts of England, find a positive impact on primary school students' performance in English and science, though not for mathematics. Campione et al. (2015) present a counterfactual evaluation of the effect of resources allocated for purchasing ICT school equipment on Italian 6th grade students achievement. Despite the substantial economic investment (around 1500 Euros per student over a three year period), results are very small and the authors conclude that the intervention has been far from being cost effective. Barrera-Osorio and Linden (2009) present the evaluation of a program aiming to integrate computers into the teaching of language in Colombian public schools. Overall, the program seems to have had little effect on students' test scores and other outcomes. Cristia et al. (2012), using data from primary schools in rural Peru, analyze the impact of a large-scale randomized evaluation of the "One Laptop per Child"

(OLPC) program. They find no evidence of effects on test scores in math and language while some positive effects are found in general cognitive skills.

A few studies have looked, among ICT related teaching practices, at the role of computer-aided instruction (CAI), namely the use of computers to teach things. These studies in general use a simple dichotomous variable capturing the usage of CAI. Angrist and Lavy (2002) find that computer aided instruction (i.e. computer software or instructional computer programs) does not appear to have had educational benefits that translated into higher test scores. Rouse and Krueger (2004) show that there is no effect on language acquisition or on actual readings skills of an instructional computer program designed to improve language and reading skills of 3rd and 6th grade students having difficulty learning to read. Few papers find positive effects. Barrow et al. (2009) find that students randomly assigned to computer-aided instruction score significantly higher on a pre-algebra and algebra test than students randomly assigned to traditional instruction. Banerjee et al. (2007) find that the introduction of a computer-assisted learning program focusing on math for children in grade 4th had a substantial positive effect on children's math academic achievement, although one year after the programs were over, initial gains weakened significantly.

Altogether these findings seem to suggest that ICT use is no better (and may even be less effective) than other traditional teaching methods. A potential explanation may be that the introduction of computers may have displaced schools resources or educational activities which, had they been maintained, would have prevented a decline in student achievement. Another reason for the weakness of the effects of ICT in schools may be the difficulty in actually integrating ICT into the educational practice. The availability of ICT related educational devices (such as computer, software or educational programs) is not enough to improve student achievement, but it is the actual practice that teachers make of these devices to make the difference. In other words, teachers are the key factor to a successful introduction of ICT in schools. Exactly as in other productive processes, the effect of introducing a new technology depends on the kind of use that is made of this latter and by the ability to absorb and make use of this technology. The key to an effective use of ICT in education is not technology itself, but the actual practice of teacher and teachers' digital literacy, level of ICT skills and understanding (OECD, 2001). [1] In this perspective, Falck et al. (2015), using data from the 2011

[1] In spite of the difficulty in defining a good teacher, empirical evidence highlights the existence of dramatic differences in teacher quality, also within schools, but these differences are not strictly correlated with observable teacher characteristics such as gender, race, experience, credentials and training, which are instead highly correlated with teachers' compensation (Dee, 2005 and 2007; Hanushek 1992; Rivkin, Hanushek, and Kain 2005; Boyd et al. 2005; Kane, Rockoff, and Staiger 2006). It has also been argued that, while teacher quality measured by teacher fixed effect is important for student achievement, its variation is driven by factors that are difficult or almost impossible to measure (Rockoff 2004). However, identifying factors driving these differences is important in order to design policies aimed at promoting teacher effectiveness. In the absence of consensus regarding which teachers' characteristics impact most on students' achievement, teacher effectiveness is often evaluated using students' achievement gains (value added approach). This approach however presents a number of limitations (see the discussion in Kane et. al 2010).

Trends in International Math and Science Study (TIMMS), show that the null effect of classroom computer on student achievement is a combination of positive and negative effects of specific computer use. In fact, they find positive effects of using computers to look up information and negative effects of using computers to practice skills,.

More in general, the importance of what teachers do in the classrooms has been emphasized in the recent literature on the effects of teaching practices on students' academic performance. More specifically, researchers have lately begun to shift attention from what teachers are (in terms of observable characteristics) to what teachers do, trying to identify the teaching practices that matter most to student achievements. Recent papers has focused on the effect of traditional versus modern teaching style, using in some cases classifications of teaching practices proposed by educational researchers. Results generally show that teaching style matters, but empirical evidence is not conclusive as regards the comparative effectiveness of modern and traditional practices. Aslam and Kingdom (2011) find that a large number of process variables, such as asking questions from pupils during lessons or quizzing students on past lessons, raise pupil mark. Schwerdt and Wuppermamm (2011) show that a shift from problem solving to lecture style presentation results in an increase in student achievement. Conversely, Van Klaveren (2011) finds no relationship between the proportion of time that teachers spend on lecturing style teaching and the performance of Dutch students who are in their second year of secondary school. Lavy (2011) finds that both traditional-style teaching (classroom teaching that emphasizes the instilment of knowledge and comprehension) and modern-style teaching (use of techniques that endow pupils with analytical and critical skills) have a strong positive effect on pupil achievement. Zakharov et al. (2014) find that test-specific homework exercises' has a positive and significant effect on student performance.[2]

Bringing together the literature on the effects of ICT at school and the literature on the effects of different teaching practices on student achievements, in this study we use a unique and rich matched student-teacher dataset from Italy to investigate the effect of ICT-related teaching practices on students' math and Italian achievement. We adopt an identification strategy that exploits within student between-subject variation to control for unobserved students' traits. Furthermore, the specific Italian institutional setting, prohibiting class choice, helps us circumventing potential non-random sorting of students to teachers because the actual class groupings is random.

The main contribution of this paper is to test linkages between computer-based teaching methods and student achievement and to provide evidence on which ICT practices are most effective to improve

[2] Metzler and Woessmann (2012) focus on teacher knowledge of a specific subject. They show that it is relevant for students' achievement, but this effect also depend on the teacher-student match in ability and gender.

learning. As far as we know, Falck et al. (2015) is the only study analyzing the effect of computer-based teaching practice on students' outcomes. However, their analysis refers to the students' use of computers during classes and it is limited to three computer-based activities (look up ideas and information, practice skills and procedures and process and analyze data). With respect to them, we focus mainly on ICT-related practices performed by the teachers and we consider a much greater array of ICT-related teaching methods, covering a broader spectrum of teaching-related activities both in the classroom and outside, both with students and alone. The survey we are using contains many detailed questions on the use of ICT in teaching that allows us identifying five distinct teaching practices. More specifically, we consider "backstage activities", such as preparing and printing files to be handled out in class; computer use aimed at knowledge transmission during lessons, such as projecting slides or sharing files with students; teaching practices implying active involvement of students through the use of general or specific software; media education practices, such as teaching students how to use social media or blogs; communication enhancing activities, favoring teacher-to-teacher collaboration and communication with students and families.

A key point to take into account is that the previous practices might have a different effect depending on teachers' ICT knowledge: the lack of ICT knowledge makes teachers anxious about using it, mainly in classrooms of students whose ICT knowledge is higher than their own one. Since ICT skills are much higher in the youngest cohorts, this may be a critical issue especially in countries, such as Germany, Italy, the Netherlands and Sweden, characterized by a large proportion of ageing teachers in secondary schools. The 2011-2012 EU survey actually shows that students' use of ICT at school is related to teacher's confidence level in her ICT and social media skills. An important contribution of our paper is that, when estimating the effects of teaching practices on students' achievement, in addition to a wide range of teachers' characteristics, we can control for both a subjective and an objective measurement of teachers' digital skills. This latter is measured by means of teachers' score in a detailed ICT performance test. Moreover, we have also information regarding ICT-related training, which may affect both teacher's ICT knowledge and its pedagogical use through specific practices.

Finally, an important factor we control for are teachers' beliefs about ICT use for teaching and learning. Existing evidence shows that these latter affect the frequency of students' ICT use in schools more than the availability of infrastructures: student taught by teachers positive about ICT use in education, but facing low access and high obstacles to use ICT at school, report more frequent use of ICT during lessons compared to students taught by teachers having high access to ICT, but being less positive about the usefulness of ICT for teaching (2011-2012 EU survey).

The results from this study provide the first evidence in the economic literature on the effect of a wide variety of ICT-related practices on students' outcomes. We find that the effect of computer-based teaching methods is quite heterogeneous. ICT-related practices increase student performance mainly if they channel the transmission of teaching material or if they are used to teach the students a critical use of internet. We also find a positive effect of communication-enhancing practices, while a negative effect is found only for practices requiring a more active involvement of students in class.

The remainder of the paper is structured as follows: the next section presents a potential classification of computer-based teaching methods and hypotheses on their effects on students' achievement; Section 3 describes the data; Section 4 explains the empirical strategy; Section 5 presents results; Section 6 concludes.

2. ICT-related teaching practices and academic achievement

Educational research has clearly pointed out that teachers and the actual use of ICT by teachers are crucial determinants of the way ICT is adopted and used in the classroom (OECD 2001). In this perspective, the existence and availability of ICTs *per se* should not affect student learning and achievement, but its impact depends on whether and how the new technologies are integrated and used in the teaching and learning process. ICT can improve teaching and hence influence students' learning by either enhancing what is already practiced or introducing new and better ways of teaching. Educational research has classified ICT-using teaching practices in a number of ways. A meaningful one for our empirical analysis classifies these practices according to their level of pedagogical innovation.

The first and more common dimension of teachers' use of ICT takes place in the "background" of their professional activity. This latter refers to preparing lessons and using the computer to perform activities such as preparing slides, printing out teaching material, preparing tests, etc. The impact of a "background" use of ICT on students' learning is twofold: on the one hand, the enormous and easy availability of textual and audiovisual content to be used for teaching can make lessons more complete and attractive; on the other hand, self-production of content that ICT offer can help teachers customize their teaching more effectively. In an evaluation of the "Laptops for teachers" program of the British Government (2002-2004), teachers who had been equipped with a laptop report having extended their capacity to access resources and saved time for lesson planning and preparation (Cunningham, 2004). The majority of teachers in developed countries already use ICT to prepare their lessons or to access teaching material on the web. More than 95% of European teachers report to prepare lessons or assessments to be administered in the classroom using digital tools (European Schoolnet, 2013; see also Balanskat et al. 2006). Teachers believe that preparing their lesson online has positive effects on the quality of their teaching (Ramboll Management 2006; Condie & Munro, 2007).

A second dimension of ICT use by teachers with possible impacts on students' learning relates to practices favoring knowledge transmission in the classroom, such as sharing files with students or using web-sites during lessons. Digital tools can be used as a support for delivering information and concepts more effectively and efficiently, mainly through the projection of images and text. It has been shown that computer use during lessons as a support for teachers pushes them to plan their lessons more efficiently (Higgins, 2005; Balanskat et al. 2006) and makes lessons more attractive for students (Ramboll Management 2006; Balanskat et al. 2006), clearly impacting on intermediate outcomes such as motivation and behaviour (Condie & Munro, 2007). Interactive whiteboards have a positive effect on student motivation levels (Higgins 2007) where the "visual appeals" of projected presentations seem to be the main contributor to this increase (Smith et al., 2006). However, some have casted doubts on the persistence of this association, claiming that a "novelty factor" could be at work and that consequently the effect could vanish when technology in schools will not anymore be a novelty (Di Gregorio et al., 2009).

A third main dimension of ICT use in the classroom concerns the active involvement of students, for instance with general or specific software. Evidence shows that teachers usually do not fully exploit the creative potential of ICT, for instance engaging students more actively in the production of knowledge (Balanskat et al 2006). While teachers' use of media to deliver information inserts itself in the traditional classroom setting, the active use of ICT by students opens unexplored horizons in the student-teacher relationship. Maybe for the complexity of this re-organization of teaching that an active use of ICT in the classroom demands, no evidence of positive impacts have emerged so far. Furthermore, a number of studies have even found negative associations between learning outcomes and the frequency of ICT use by students at school (OECD, 2011; Biagi and Loi, 2013) or for school-related purposes (Gui, 2013).

A fourth main dimension of ICT use by teachers that can be found in the literature pertains to "media education" practices. The presence of ICT in the classroom can facilitate a confrontation between students and teachers on digital risks and opportunities, whose level of awareness seem particularly poor among adolescents (Calvani et al., 2011; Gui e Argentin, 2011; Van Deursen e van Dijk, 2009) There are no available results so far of a direct association between "media education" teachers' practices and learning performance. However, there is evidence that digital supportive teachers tend to have more digitally aware students (Argentin et al., 2013) and that, in turns, a higher level of critical digital skills among students has a positive impact on their learning outcomes (Pagani et al., 2015).

The last kind of ICT use in schools is related to communication practices between teachers, students and their families, that is the use of a pc to communicate with colleagues, students and their families or to access official communications. Even among teachers who make high use of ICT, only a small proportion report that the new technologies are used also to increase collaboration between teachers (OECD 2001), for instance co-producing knowledge with other colleagues inside and outside the school. Research in the evaluation of ICT investment educational policies show a perception of positive effects on teaching quality among teachers (Ramboll Management 2006): pupils and teachers seem to benefit from good home–school links using ICT (Condie and Munro, 2007).

3. Data

We use data from three sources. The first is the survey we conducted on a sample of students selected from all second-year upper secondary school classes (10^{th} grade) in the Lombardy region and stratified by school type and geographical position. The sample is representative of all 10^{th} grade students in the Lombardy region. The survey has been carried out in April 2012 and it contains interviews to a sample of 2327 students from 117 classrooms randomly drawn from 60 schools.

The data include information on socio-demographic characteristics of the students, on past and current academic performance[3] and on extra-curricular activities. In addition, the survey provides an in-depth description of how young people use digital media today: it contains a wealth of information on digital devices owned and used, on the frequency and kind of use of the internet and on the presence of digital devices and of computer labs in school.

The second source of data is a survey on the teachers of the previous survey's target students. It contains information on socio-demographic characteristics of the teachers such as gender, birth year, highest education level obtained, field of study and graduation grade. There are also some information regarding the teachers' job position (experience, tenure, type of contract, the number of hours taught weekly and the subject taught), training (including ICT-related one) and the reasons for teaching, which enables us to have an important proxy for motivation. The questionnaire then focuses on teachers' use of ICT outside of their job, asking how frequently they use a computer, how many hours they spend on the internet daily and whether they have a Facebook profile. An interesting part of the survey asks teachers how often they use computers for a wide array of teaching-related usages, such as creating and projecting slides during classes, assembling digital material or files to deliver to the students, showing students specific educational websites or using a pc to communicate with

[3] We asked each student whether she has been flunked in the past, which score she obtained at the lower secondary school final examination, the average grade obtained in Italian, math, foreign language and science and a self-reported evaluation on the students' current academic performance

colleagues, students and their families. The teachers are also asked whether they use common or specific education software, whether they help students for ICT-related problems or explain how to carry out an internet search using encyclopedias or web sites. Then, all the teachers report how many hours per month they use an interactive whiteboard, a pc with a projector or a pc to work outside of the class. The final part of the questionnaire regard teachers' opinions on the use of ICT as a tool to facilitate learning, and ask a self-evaluation of their ICT related knowledge[4].

A very valuable feature of the dataset is that an in-depth standardized test is administered to the same teachers filling the questionnaire, with the aim of investigating their digital knowledge. The test has been developed with the intent to cover some of the main aspects of what literature defines as 'digital skills'. The test consists of 15 closed-ended questions. The specific digital skill that is evaluated is the "critical digital skill", that is the teachers' ability to assess the reliability of webpage content or to identify correctly the sources and the risks related to internet use. More specifically, teachers were asked to analyze website addresses and browsers' search results and to prove their knowledge of the functioning of popular websites among the youth, such as Facebook, YouTube, Yahoo Answers or Wikipedia.[5] We built a score describing teachers' critical digital knowledge based on the number of correct answers provided in the test and then we normalize it.

The third source of data is from the Italian National Institute for the Evaluation of the School System (INVALSI), which regularly carries out standardized tests to assess the learning levels of pupils at various grades.[6] We consider the math and Italian tests administered to 10th grade pupils at the end of the 2011/2012 year, along with a pupil's questionnaire. This latter contains additional information on students (such as their level of confidence with INVALSI-type questions) that can complement that provided by the other survey we are using. The math and Italian standardized test scores represent our dependent variables.[7]

We merge the students' survey with the INVALSI dataset. We drop students from vocational school, to whom the INVALSI test is not administered, and observations with missing values in the INVALSI

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[4] The specific question is: All in all, do you think you are prepared to use the new ICTs as a teacher? Please answer using a 10-point scale (where 1 is not prepared at all, 10 is absolutely prepared).

[5] Examples of questions are: In your opinion, who writes the Wikipedia entries? Choose only one of the following four possible answers: 1. Those who are registered on Wikipedia website and were accepted as collaborators; 2. The creators of the website and other paid employees; 3. There are no limitation: everyone can write them; 4. Only a pool of experts chosen by Wikipedia.

Are the following sentences true or false?

1. When you publish something on Facebook you can make it accessible only to some of your Facebook friends
2. Information on Yahoo Answers is reliable because published answers were checked by experts
3. You can sign a contract with Youtube to get money for the videos you upload

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

[7] Math and Italian constitute the main subjects in Italian schools and serve as key indicators of academic performance.

test score. After keeping only math and Italian teachers, we merge the students' dataset with the teachers' dataset using a classroom identifier as merging code.

We keep in the sample only those classes for which we observe both math and Italian teachers and end up with 868 students (1736 subject /students observations) and 94 teachers (47 for each subject). Table A1 in appendix shows the descriptive statistics of the students' sample.

TABLE 1 AROUND HERE

Table 1 reports the main descriptive statistics of a set of standard teacher characteristics by subject. Italian teachers are slightly younger, more educated and graduated with a higher mark when compared to math teachers. They also teach more hours a week. When we look at the choice of becoming a teacher, we can see that around 33 percent of Italian teachers and 47 percent of math ones took this career because of their passion for the subject. Conversely, 44 percent of Language teacher and 36 percent of math chose this career because they wanted to teach or being able to work with young people. The remaining share in each sample became teachers because of the lack of other better job opportunities. On average the students in our sample have a better performance in the National INVALSI test in Italian than math and, as it can be seen in Figure 1 and Table 1, the within student difference in the test scores is almost always positive (only 8% exhibit a better performance in math). Similarly, the average grade in the first term is slightly higher in Italian than in math. Students believe that math is more important than Italian in life, work and school career.

A number of explanations are consistent with this result: for example, students may be more able in Italian than in math or the first may be an easier subject than the latter. Furthermore, in Italy it may also be the case that students are more trained in language than in math to answer questions like those in the INVALSI test. Actually, 45 per cent of the students in our sample have declared to be familiar with INVALSI-type questions for language, while the corresponding share for math drops to 26 per cent (see Table 1) [8].

To deal with this issue and make the score in the two subjects comparable, as in previous studies we standardize the INVALSI test score by subject (Aslam and Kingdom 2011). We shall use this standardized variable, which for each subject by construction has mean 0 and standard deviation 1, as the dependent variable of the following econometric analysis.

FIGURE 1 AROUND HERE

[8] Up to these days, math written tests and exams in Italy are basically open questions or problems in Italian secondary schools.

In Table 2, we focus on the diffusion of ICT related variables by teachers' subject. Compared to math teachers, Italian teachers have a lower probability of attending an ICT related training course, spend more hours on internet, have higher propensity to use a pc every day at home and to have a Facebook profile. A great majority of Italian teachers believe that ICT is useful in preparing lectures, while only around half of math teachers shares this opinion. Regardless of the subject taught, two out of three teachers are in favor of ICT use in teaching, while one out of three thinks that ICT introduced an important change in teaching. Finally, only 15 percent of math teachers and 5 percent of Italian ones believe that ICT have a positive effect on her own teaching. Quite interestingly, Italian teachers performed on average better than math ones in the test on critical digital knowledge, but their subjective perception is lower. In Figure 2 we plot the teachers distribution with respect to both objective and subjective ICT knowledge and investigate the relationship between the two. More specifically, in the first panel of Figure 2 we plot the distribution of teacher correct answers in the ICT critical knowledge test we submitted.

TABLE 2 AROUND HERE

The maximum number of correct answers is 12 over a total of 15 questions and the average number of correct answers is between 8 and 9. When we compare the subjective evaluation of ICT knowledge with the result of our test, we find that the correlation is rather low and a number of teachers who believed themselves quite proficient in the use of ICT performed rather poorly in our test. This is rather common when self-evaluated abilities are compared to objective ones. Mabe and West (1982) show that many unobservable characteristics determine the difference between self-evaluation and objective evaluation. This difference turns out to be related to individual characteristics (i.e. high intelligence, high achievement status and internal locus of control) and to specific conditions of measurement (the possibility that the self-evaluation would be compared to the objective one, the experience in self-evaluation, anonymity and instructions of the self-evaluation). Having this kind of information will turn out to be extremely precious in our estimation strategy, as it will allow us to control both for objective and self-evaluated ICT related abilities, which are likely to influence the way the teacher relates to and actually uses ICT.

Finally, we asked the teachers how many hours per month they use the interactive whiteboard (IWB) or a pc with a projector while teaching. Italian teachers use the IWB less and the pc with a projector more than math teachers. There's no difference in the use of a pc in class on their own.

FIGURE 2 AROUND HERE

As regards the use of ICT in teaching, we asked the teachers how often they used their personal computer to carry out an ICT related practices while preparing to or during their teaching. For each question, we report the distribution of answers separately for the two subject in table A2 in appendix. Among the many practices, it is difficult to find a clear pattern. Some of the practices are widely diffused, like preparing test or printouts, while other are very rare, like enrolling in online training course. In some practices there are wide differences in the two subjects, for example, many students have teachers who use common or specific software in math, and very few in Italian, while the contrary is true when we look at preparing printouts or teaching how to use an online encyclopedia. Furthermore, these practices are clearly correlated one with the other for several reasons, such as the school policy towards the use of ICT in teaching, the nature and contents of the subject taught, individual teaching style and other unobserved teacher characteristics. In order to organize so much information and to ease interpretation of the main results, we run a Principal Component Analysis (PCA) to identify and measure indexes of different teaching ICT practices. The PCA was conducted on the original sample of around 700 teachers and results are actually based on 622 cases (the ones answering all the items considered in the analysis). Despite our focus on Italian and math, we considered here the entire available teacher sample, for two reasons: a.

We adopted an exploratory approach considering all the items investigating teacher use of ICT. We selected 19 items, considering their communality and factor loadings. We kept the first five components emerging from the analyses, those with eigenvalue greater than one (a standard criterion). Moreover the screenplot examination suggested to take into account the same number of components. This model explain 62% of the global amount of variance. The lowest communality is 0.38 and each item is strongly associated only with one component (with only three partial exceptions). Table 3 reports the associations among each item and the five components.

TABLE 3 AROUND HERE

The first component loads practices that imply the use of personal computer during the lesson, such as using slides or other digital material (video, audio or website) in class or sharing files with students (not printed or to be printed), so that ICT is used to deliver information more efficiently, and that’s why we called it *knowledge transmission* practices. The second component loads practices aimed to produce skills that are not directly linked to the subject, like the awareness of digital risks (evaluation of website content or how to avoid viruses), privacy rules or netiquette in social media, or, as it is named *media education*. The third component loads practices that presume an interaction among the teacher, the students and ICT devices, such as using common or specific software in class, explaining how to study with internet or online encyclopedia. Indeed, these are activities in which each student is activated, i.e. assisted by the teacher in using the technology to reach a particular goal, like write a text or solve an equation. We label this factor *active involvement*. The fourth component loads background practices, like preparing printouts, test or lectures and we call it *backstage activities*. Finally, the last component pertain to the communication aspect of ICT, like communicate with students, family or colleagues or reading formal communication by the ministry or the school board on line. So we call this factor *communication*. Notice that the main components delivered by the PCA on a large number of ICT related practices are in line with the classification proposed and discussed in Section 2.

4. Empirical strategy

In order to assess the effect of ICT-related teaching practices, we estimate the following specification of the standard education production function:

$$y_{ijk} = \alpha + \beta_1 ICT_{ijk} + \beta_2 X_{ijk} + \beta_3 S_{ijk} + \beta_4 T_{ijk} + \varepsilon_{ijk} \qquad [1]$$

where y is the test score of student i in subject j in school k, ICT is a vector of variables measuring the teacher ICT-related knowledge and practices, X is vector of student characteristics, S of school characteristics and T of teacher (and class) characteristics.

The error term ε captures all the unobserved factors which influence student performance and it can be specified as follows:

$$\varepsilon_{ijk} = \mu_i + \theta_j + \varphi_k + v_{ijk} \qquad [2]$$

where μ, θ and φ are, respectively, student, teacher and school time-invariant unobserved factors.

Estimation of equation [1] by OLS yields biased estimates if the unobserved factors are correlated with the variables in the ICT vector. This may be the case when both teachers and students are not randomly distributed across schools (and across classes within schools) and hence a specific match student-teacher is endogenous. Endogenous sorting may arise because families choose specific schools for their children and, in some cases, they may also choose specific classes within a school, also on the basis of the teacher quality and reputation. On the other hand, there is evidence showing that teachers prefer to work in schools with higher-achieving students, while they have heterogeneous preference in terms of other students observable characteristics, such as race and ethnicity (Hanushek 2004). Schools which are able to employ more effective teachers can in turn attract the highest achieving students and hence the unobserved student heterogeneity is likely to inflate differences between schools in teacher quality. Despite this evidence of positive sorting between "good" teachers and "good" students, predicting the direction of the actual bias is difficult, since, within schools, it also depends on the principal's objectives (Hanushek and Rivkin 2012): an egalitarian principal will place the higher quality teachers in classes with more disruptive children, while a principal who wants to retain the senior staff will match the more experienced teachers with the best students.

In our case, the specific Italian institutional setting allows us to partly address the problem of endogenous matching between teachers and students: once families choose the school for their children, the latter are usually randomly assigned to a certain class – regardless families' or children's preferences for specific teachers or schoolmates. Hence, the class is not identified by a certain grade, but by a subsection of a certain year. Furthermore, the classroom is the same for all the subjects taught and for the entire duration of high school: minor changes each year are due to students who have to repeat a year (this happens frequently in high schools) or who change school (a rare event) or who move to another town (an exceptional event). In this perspective, the same group of students (and teachers) can expect to be together for years. Each class does everything together, staying all day in the same room; it's the teachers who go from classroom to classroom, except those whose subjects require labs or other special equipment. Everyone in a class takes the same courses because there are no electives in Italian high schools: the pool of subjects is determined by the type and of high school and program initially chosen; if the student realizes that this is not what she is really interested in, she will change the program or even school. This is usually done by the end of the first year of high school (i.e. 9th grade) because later changes are usually very costly in terms of required prerequisites for the new program/school, often implying to start again from the first year. Nonetheless, in our estimations, we cluster standard errors within each class.

Although the features of the institutional setting attenuate the problem of sorting between students and teachers, student achievement may be influenced by (unobserved) student, teacher and school factors. To deal with these sources of endogeneity we follow the approach proposed by Dee (2005 and 2007) and use a within-student between-subject estimator, which allows to fully control for unobserved heterogeneity of both schools and students by taking differences between two subjects (in our case, Italian and math, named I and M respectively) in the following way:

$$y_{iIk} - y_{iMk} = \alpha_I - \alpha_M + \beta_{1I}\, ICT_{iIk} - \beta_{1M}\, ICT_{iMk} + (\beta_{2I} - \beta_{2M})X_i + (\beta_{3I} - \beta_{3M})S_i + \beta_{4I}T_{iIk} - \beta_{4M}T_{iMk} + \omega_i \qquad [3]$$

where: $\omega_i = (\theta_I - \theta_M) + (v_{iI} - v_{iM})$ [4]

If we assume, as in Dee (2005), that coefficients across subjects are equal, equation [5] reduces to:

$$y_{iIk} - y_{iMk} = \beta_1 \Delta ICT_i + \beta_4 \Delta T_i + \omega_i \quad [5]$$

where identification of the coefficients relies on differences between subjects for the same student and on uncorrelation between the error term and the right hand side variables. Notice that the second term in brackets of the error term in equation [4] may still contain student's subject specific unobserved factors (such as a differential aptitude toward each subject), which influence student performance and can be correlated with ICT teaching practices. In order to take into account this potential source of endogeneity, we add to equation [5] some subject specific students' variables, namely: the grade in the first term of the year in each subject, the familiarity with the INVALSI test and their beliefs relative to the importance later in life of each subject. The first variable transforms the equation in a kind of semi value-added specification.

With this estimator, we fully control for both school and class unobserved heterogeneity, but we cannot rule out potential endogeneity caused by unobserved teacher-specific factors. We address this problem exploiting the richness of the survey and controlling for a number of teacher characteristics (such as gender, age, education, training, work experience, tenure, type of contract, weekly hours taught), including some controls usually not available in previous studies, such as a proxy for teacher's innate ability (captured by their graduation grade) and for their motivation (captured by the main reason they chose to become teachers).

Another source of endogeneity of ICT related practices may be due to self-selection of teacher into ICT adoption. In fact, those who use ICT are teachers with more unobservable easiness, love or ability with ICT, but they may have also other unobservable characteristics that increase their students' achievement. This will lead to biased estimates of the coefficient β_1 in equation [5]. We address this issue in two ways. First, we control for the teacher ICT use and knowledge, both subjective and objective, and for teacher believes in the role of ICT in schools. We thus partially take into account the unobserved component of teacher specific error component that can be related to ICT adoption and use. Secondly, we run a robustness check and estimate equation [5] using a different dataset, TIMMS 2011, in which we have science and math students test score for students in the last year of junior high school. In Italy the same teacher teaches these two subjects, so we can add to the specification a teacher fixed effect and control for the time-invariant component of unobservable teacher traits that may affect both ICT adoption and student achievement.

5. Results

Table 4 presents our main estimations when we consider the ICT related practices we computed from the principal component analysis[9]. We first consider only the five factors together with a standard set of teacher characteristics (gender, age, education, college final grade, a polynomial of the second order for experience and tenure, weekly teaching hours and their motivations). Teaching practices are mildly significant. Then we add controls for students' subject specific characteristics (Column 2). Again, most of the estimates on ICT teaching practices are not statistically significant. Finally, in column (4) we add teacher ICT related characteristics (the subjectively and objectively evaluated knowledge, their beliefs on ICT and teaching, how much they use technology and whether they attended an ICT related training course). The five factors are now both jointly (as shown by the F-tests at the bottom of the column) and individually significant. In fact, by adding these variables, we are probably able to better take into account the unobserved teacher self-selection in ICT use. Thus, the last column is our preferred specification. Our results show that ICT-related teaching practices are important for student performance. Almost all the practices we are considering have a positive effect on student achievement, with the exception of those entailing an active involvement of students. This result confirms that there could be a decrease in learning performance when ICTs are used intensively by students at school (OECD, 2011).

TABLE 4 AROUND HERE

To sum up, ICT-related teaching practices increase student performance if they help the teacher to get further material to prepare his/her lectures (and hence they presumably increase his/her subject specific knowledge), if they channel the transmission of teaching material, if they increase the digital awareness or critical digital skills among students and if they speed up and make easier to communicate with students, families and colleagues.

We then move a step forward and try to see whether other less refined measures of ICT's use produce similar results, in order to see if we can reconcile our results with the previous literature related with ICT adoption. With our specification in the Italian school setting, we can't use the availability of IWB

[9] We standardize each factor in order to have zero mean and standard deviation one.

or pc in class because both math and Italian lessons are usually taken in the same class. Thus we use some kind of intensity of ICT use in each subject as alternative to our factors. Table 5 presents the estimations of equation [5] when we consider the variables that measure the use of ICT in a simpler way. In column (1) we consider the number of hours per month in which the teacher used a IWB, in column (2) a pc with a projectors, in column (3) a pc for her own use while in class. We add the three variables to gauge the total amount of ICT use in class in each subject in column (4). Finally in column (5), we define a dummy that takes the value 1 whenever the teacher uses at least one hour per month any of the three types of ICT devices. This dummy is similar to the answer to a question asking teacher "do you use a pc or a IWB in class?" We add to the equation the usual controls describe above, in our main specification. We find that using IWB has no significant effect on student performance, while the use of a pc alone or with a projector reduces student achievement. The same result is found when we sum the hours of ICT use in class, while the dummy turns out not statistically significant. In general, these results are in line with the educational literature mentioned above and confirm that the adoption of ICT (pc with or without a projector and IWB) *per se* is not necessarily beneficial for student learning, suggesting that student achievement will not benefit from efforts aimed to simply increase ICT availability and infrastructure indiscriminately.

TABLE 5 AROUND HERE

5.1 Robustness checks

Previous results have been obtained using a within-student between-subject estimator, which allows to fully control for unobserved heterogeneity at both school and student level by taking differences between ICT-related teaching practices in math and Italian. We controlled for teacher characteristics exploiting the richness of the survey that allowed us controlling for a number of teacher variables, including proxy for teachers' innate ability and for their motivation. Despite of this, we cannot rule out that there are unobserved factors that influence both adoption of specific computer-based teaching methods and students' outcome. As a robustness check for our results, we replicate estimates using a different dataset that allows us to use a within-teacher within-student estimator. Specifically, we use data from the 2011 Trends in International Math and Science Study (TIMMS) for 8th grade Italian students (who are two years younger than our students).[10] TIMSS data contains information on students' achievement in math and science and detailed information on the corresponding teachers. Since in Italy in 8th grade these subjects are taught by the same teacher, we reach identification

[10] TIMMS data are available for 34 countries. However, we use data only for Italy because we want to compare estimation results with those obtained using our dataset.

exploiting the variation in the use of ICT-related teaching methods in different subjects taught by the same teacher to the same students.

The TIMSS survey contains two questions asking teachers information about the use of PC in class. The first one covers mainly activities that entails each students having a computer and carrying on assignment like look up ideas and information or process and analyze data. The second one is related to frequency of use in class of specific software.[11] These questions refer to activities that are similar to those included in the teaching practice we have defined above active involvement of students during lessons, for instance using general or specific software or explaining how to use website to study or online encyclopedia.

To aggregate them, we built two dummy variables (one for math and one for science) taking the value of one when the teacher asks students to use a pc "*daily or almost daily*" or "*once or twice a week*" , or when he/she answers to use software for teaching as a basic or supplementary resource.

We estimate a regression similar to the one specified in equation [5]. However, given that the same teacher teaches the two subjects, we can fully control for subject-invariant unobserved teacher characteristics that influences both ICT-related teaching method adoption and students' performance. In the preferred specification, we controlled for several other subject-specific variables both at teacher and at student level. [12]

Results are in Table 6. Despite the different dataset, subjects and students' grade, they confirm our previous results. In column (1) to (3) we consider one practice at a time, we add all of them in column (4) and finally we consider the aggregated dummy defined above, which is our preferred specification. In this last column, we find that ICT-related teaching practices implying active involvement of students during lessons have a negative effect on their performance. We interpret this result assuming that an active use of ICT in the classroom may displace time resources for other educational activities, which, were, they maintained, would have prevented a decline in student achievement. This result is in line with previous studies that have found negative associations between learning outcomes and the frequency of ICT use by students at school (OECD, 2011; Biagi and Loi,

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[11] The precise wording of the first question is:
How frequently (daily or almost daily; once or twice a week; once or twice a month; never or almost never) do you ask your students to use a pc to do the following activities during math/science lessons?
i. Practice skills and information
ii. Look up ideas and information
iii. Process and analyze data
The second question is:
When you teach math/science in this class, how do you use software for teaching math/science? The possible answers are: *As a basic resource during lessons; as a supplementary resource; Not used.*

[12] As regards teacher-level variables, these are: weekly hours of teaching, self-evaluation of own ability to teach, not computer-based teaching methods (e.g. ask students to memorize facts, principles, rules or procedures or to relate the lesson to their daily lives), homework frequency and length and subject-specific training. As for student-level subject-specific variables, they refer to self-evaluation of own performance and to attitudes towards the subject.

2013) or for school-related purposes (Gui, 2013). Given the complexity of the re-organization of teaching implied by an active use of ICT in the classroom, our result suggests that teachers do not yet fully exploit the creative potential of ICT, in particular when it is individually used by each student.

TABLE 6

Overall, estimates using TIMSS data, where we can fully control for teacher subject-invariant characteristics, are in line with our previous results, suggesting that the rich set of controls for observable teachers' characteristics and of proxy for their unobservable traits (e.g. motivation or innate ability) allow us to properly control for unobserved teacher heterogeneity.

6. Conclusions

In this paper we exploit a unique and rich student-teacher data-set to study the effect of a wide array of measures of teacher ICT-related teaching practices on student achievement. To control for different sources of unobserved heterogeneity, we use a within-student between-subject estimator and controls for a huge set of teacher ICT related characteristics. In general, ICT-related teaching practices increase student performance if they help the teacher to get further material to prepare his/her lectures (and hence they presumably increase his/her subject specific knowledge) or if they channel the transmission of teaching material or are used to increase students awareness in ICT use. We also find a positive effect of ICT using communication-enhancing practices. Instead, a negative effect is found only for practices requiring a more active role of the students in class in using ICT, probably because these practices are more time consuming and less effective.

From a policy point of view, these preliminary results suggest that ICT *per se* is not necessarily beneficial for student learning and a mere availability of more technology in school, as already shown by previous descriptive studies, may not be enough to foster students achievement. But some ICT-related practices may indeed increase student performance.

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Table 1: Teachers' and students' characteristics by subject

VARIABLES	(1) Language Mean (SD)	(2) Math Mean (SD)	(3) Difference (1)-(2) (SE)
Teacher characteristics			
teacher male	0.237	0.134	.103
	(0.426)	(0.340)	(.018)
teacher age	49.11	51.29	-2.17
	(9.697)	(8.260)	(.432)
Phd	0.258	0.192	.065
	(0.438)	(0.394)	(.020)
college final grade	108.4	98.10	10.25
	(3.297)	(8.344)	(.304)
permanent contract	0.775	0.917	-.141
	(0.418)	(0.276)	(.017)
weekly teaching hours	6.540	4.531	2.00
	(1.979)	(1.728)	(.089)
Experience	19.67	23.03	-3.361
	(11.01)	(8.724)	(.477)
experience squared	508.1	606.6	-98.46
	(448.8)	(397.5)	(20.35)
Tenure	9.733	11.80	-2.07
	(8.125)	(8.858)	(.408)
Tenure squared	160.7	217.7	-56.98
	(221.5)	(270.0)	(11.85)
Motivations			
Responding to my need	0.123	0.0184	0.105
	(0.329)	(0.135)	(0.0121)
Passion for the subject	0.333	0.470	-0.137
	(0.472)	(0.499)	(0.0233)
Passion for teaching	0.278	0.252	0.0253
	(0.448)	(0.435)	(0.0212)
Willing to work among youth	0.160	0.104	0.0565
	(0.367)	(0.305)	(0.0162)
Lack of other job opportunities	0.106	0.156	-0.0495
	(0.308)	(0.363)	(0.0161)
Students subject specific variable			
1st term grade	6.592	6.330	.262
	(0.965)	(1.440)	(.058)
Familiarity with INVALSI-type tests	0.450	0.262	.189
	(0.498)	(0.440)	(.022)
Subject important in life	0.505	0.889	-0.385
	(0.500)	(0.314)	(0.020)
Subject important to learn other subjects	0.461	0.865	-0.404
	(0.499)	(0.342)	(0.0205)
Subject important for my future school career	0.457	0.652	-0.195
	(0.498)	(0.477)	(0.0234)
Subject important for my future work	0.472	0.781	-0.309
	(0.500)	(0.414)	0.0220
Invalsi test score	78.055	58.24	19.81
	(11.38)	(17.18)	(.699)
Observations	868	868	1736

Table 2: Teachers' ICT related variables: Summary statistics by subject.

VARIABLES	(1) Language Mean (SD)	(2) Math Mean (SD)	(3) Difference (1)-(2) (SE)
Teacher ICT critical knowledge test:			
Number of correct answers (from 1 to 15)	8.74	8.51	.229
	(0.080)	(0.083)	(.11)
ICT subjective assessment (from 1 to 10)	6.029	6.438	-0.409
	(1.511)	(1.686)	(0.0768)
ICT related training	0.364	0.551	-.186
	(0.481)	(0.498)	(.023)
ICT general use in teacher spare time			
Number of hours on internet everyday	1.508	1.267	0.241
	(0.902)	(0.866)	(0.042)
Use pc every day at home	0.926	0.895	0.0311
	(0.261)	(0.307)	(0.014)
Have a facebook profile, Use pc every day at home	0.374	0.289	0.0853
	(0.484)	(0.454)	(0.023)
ICT related beliefs			
In favor of ICT use in preparing lecture	0.788	0.568	.22
	(0.409)	(0.496)	(.021)
In favor of ICT use in teaching	0.643	0.615	.027
	(0.479)	(0.487)	(.023)
Think ICT introduced important change in teaching	0.324	0.303	.021
	(0.468)	(0.460)	(.022)
Think ICT had very positive effect on her own teaching	0.0553	0.151	-0.95
	(0.229)	(0.358)	(.014)
ICT use in teaching			
Number of hours using the interactive multimedia board	.369	.951	-.581
	(1.217)	(3.157)	(.114)
Number of hours using a pc and projectors	1.586	.942	.644
	(3.088)	(.053)	(.117)
Number of hours using a pc on their own	2.66	2.24	.415
	(6.62)	(5.34)	.288
Observations	868	868	1736

Table 3: Rotated factor loadings (pattern matrix) - principal components analysis

	Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Uniqueness**
Use slides	**0.8759**	0.0863	0.1143	0.0855	0.0571	0.2017
Use digital material	**0.8726**	0.0484	0.1765	0.0405	0.0681	0.1988
Share files with students	**0.6475**	0.1225	0.2414	0.2469	0.162	0.4202
Show web-sites during lessons	**0.6916**	0.1885	0.2432	0.2018	0.0682	0.3817
Prepare printouts	0.1828	0.078	0.1272	**0.7894**	0.0232	0.3206
Prepare test	0.0488	-0.0396	0.0632	**0.7098**	0.2684	0.4162
Use internet to prepare a lecture	**0.4127**	0.0703	0.0509	**0.5515**	0.0386	0.5165
Teach students how to use Social media	0.067	**0.8335**	0.16	0.0247	0.0837	0.2676
Teach students about privacy on internet	0.1032	**0.8498**	0.0548	0.0049	0.0592	0.2607
Explain how to Find studying groups in internet	0.2035	**0.6326**	0.1774	0.0633	0.1041	0.5121
Teach how to avoid viruses	0.083	**0.5961**	**0.4559**	-0.0296	0.0653	0.4248
Teach how to Evaluate the dependence of website content	0.0723	**0.5576**	**0.4899**	0.2032	-0.0625	0.3986
Teach students how to use online encyclopedias	0.1196	0.3761	**0.6062**	0.2486	-0.1373	0.3961
Use common Software with students	0.2358	0.1702	**0.7846**	0.0611	0.1075	0.2845
Use specific software with students	0.2293	0.0607	**0.781**	-0.0259	0.1842	0.2991
Explain how to study with internet	0.2585	0.2542	**0.6262**	0.2303	0.0585	0.42
Exchange teaching material with colleagues	0.1608	0.1073	0.1524	0.1574	**0.6789**	0.4537
Use a pc to communicate with colleagues, students and their families	0.0836	0.0798	0.0795	0.1241	**0.7373**	0.4213
Follow online training course	0.3854	0.1673	0.095	-0.0274	**0.4383**	0.6215

Table 4: Within student between subjects estimation of the effect of ICT related teaching practices on students achievement.

	(1)	(2)	(3)
VARIABLES			
Knowledge transmission	0.0410	0.0388	0.220**
	(0.0755)	(0.0690)	(0.104)
Media education	0.0478	0.0418	0.200***
	(0.0566)	(0.0523)	(0.0743)
Active involvement	-0.0248	-0.0445	-0.163**
	(0.0590)	(0.0532)	(0.0704)
Backstage activities	0.0770*	0.0512	0.116*
	(0.0453)	(0.0404)	(0.0681)
Communication	0.180**	0.144**	0.256***
	(0.0746)	(0.0678)	(0.0840)
Teacher controls:			
General characteristics	YES	YES	YES
ICT related characteristics	NO	NO	YES
Student subject-specific controls	NO	YES	YES
Observations	1,736	1,736	1,736
R-squared	0.161	0.224	0.274
Number of ids	868	868	868
F-test ICT prectices	1.672	1.211	2.834

Notes: Clustered standard errors in parentheses (number of clusters: 47)
*** p<0.01, ** p<0.05, * p<0.1
All specifications include a constant and a subject dummy. Teachers' general characteristics are: male, age, phd, college final grade, permanent contract, weekly teaching hours, experience, experience squared, tenure, tenure squared and motivation dummies. Students subject-specific controls are: 1st term grade, Familiarity with INVALSI-type tests and motivations to study each subject for their importance. Teachers ICT related characteristics are: ICT critical knowledge test, ICT subjective assessment, ICT related training, number of hours on internet everyday, whether have a facebook profile, whether they use a pc every day at home, detailed ICT related beliefs.

Table 5: Within student between subjects estimations with hours of ICT use in class.

VARIABLES	(1)	(2)	(3)	(4)	(5)
IWB hours per month	0.0095				
	(0.015)				
Pc and projector hours per month		-0.063**			
		(0.026)			
Hours using a pc on their own per month			-0.032***		
			(0.008)		
Sum of ICT's use hours in class per month				-0.029***	
				(0.0061)	
Dummy use ICT in class					-0.0699
					(0.110)
Teacher controls					
General characteristics	YES	YES	YES	YES	YES
ICT related characteristics	YES	YES	YES	YES	YES
Student subject-specific controls	YES	YES	YES	YES	YES
Observations	1,736	1,736	1,736	1,736	1,736
R-squared	0.222	0.242	0.263	0.267	0.223
Number of ids	868	868	868	868	868

Notes: Clustered standard errors in parentheses (number of clusters: 47)
*** p<0.01, ** p<0.05, * p<0.1
All specifications include a constant and a subject dummy. Teachers' general characteristics are: male, age, phd, college final grade, permanent contract, weekly teaching hours, experience, experience squared, tenure, tenure squared and motivation dummies. Students subject-specific controls are: 1st term grade, Familiarity with INVALSI-type tests and motivations to study each subject for their importance. Teachers ICT related characteristics are: ICT critical knowledge test, ICT subjective assessment, ICT related training, number of hours on internet everyday, whether have a facebook profile, whether they use a pc every day at home, detailed ICT related beliefs.

Table 6: Within student between subjects estimations of active students' involvement practice using TIMMS. Subjects: math and science.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Process and analyze data	-0.0715			-0.00937	
	(0.053)			(0.0550)	
Practice skills and information		-0.183***		-0.186***	
		(0.038)		(0.0544)	
Look up ideas and information			0.0156	0.0462	
			(0.0590)	(0.0420)	
Active students involvement (dummy variable)					-0.0567*
					(0.0312)
Teacher controls					
Subject specific characteristics	YES	YES	YES	YES	YES
Student subject-specific controls	YES	YES	YES	YES	YES
Student fixed effect	YES	YES	YES	YES	YES
Teacher fixed effect	YES	YES	YES	YES	YES
Observations	6,878	6,878	6,878	6,878	6,878
R-squared	0.083	0.085	0.083	0.086	0.082
Number of ids	3,439	3,439	3,439	3,439	3,439

Notes: Clustered standard errors in parentheses (number of clusters: 176) *** p<0.01, ** p<0.05, * p<0.1
All specifications include a constant and a subject dummy. Teacher-level variables are: weekly hours of teaching, self-evaluation of own ability to teach, not computer-based teaching methods (e.g. ask students to memorize facts, principles, rules or procedures or to relate the lesson to their daily lives), homework frequency and length and subject-specific training. As for student-level subject-specific variables, they refer to self-evaluation of own performance and to attitudes towards the subject

Table A1: Students' and schools' variables

VARIABLES	(1) mean (sd)
test score	68.15
	(17.63)
student male	0.487
	(0.500)
student age	16.20
	(0.560)
Repeater	0.143
	(0.350)
medium mark in lower sec	0.296
	(0.457)
high mark in lower sec	0.347
	(0.476)
only child	0.244
	(0.430)
one sibling	0.537
	(0.499)
parents highest edu level: secondary school	0.326
	(0.469)
parents highest edu level: university	0.378
	(0.485)
petty bourgeoise	0.139
	(0.346)
clerical class	0.333
	(0.471)
service class	0.334
	(0.472)
Humanities	0.0645
	(0.246)
Foreign languages	0.0818
	(0.274)
Social science	0.0726
	(0.260)
Technical	0.162
	(0.369)
Commercial	0.172
	(0.377)
Professional	0.127
	(0.333)
Observations	1,736

Table A2: Teachers' ICT related practices: Summary statistics by subject. Row percentages.

Use slide			
	often	*Sometime*	*never*
Italian	16.36	35.02	48.62
Math	11.06	47.12	41.82
Use digital material			
	often	*Sometime*	*Never*
Italian	15.78	29.84	54.38
Math	16.59	46.08	37.33
Share files with students			
	often	*Sometime*	*Never*
Italian	15.55	52.19	32.26
Math	23.62	51.38	25
Prepare printouts			
	often	*Sometime*	*Never*
Italian	43.78	56.22	0
Math	32.95	51.27	15.78
Preparing test			
	often	*Sometime*	*Never*
Italian	54.61	45.39	0
Math	63.94	36.06	0
Show web-sites during lessons			
	often	*Sometime*	*Never*
Italian	7.26	53	39.75
Math	15.21	40.9	43.89
Use internet to prepare a lecture			
	often	*Sometime*	*Never*
Italian	55.41	35.14	9.45
Math	49.42	41.47	9.10
Use pc to communicate with colleagues, students and families			
	often	*Sometime*	*Never*
Italian	24.08	64.29	11.64
Math	42.17	49.65	8.18
Exchange teaching material with colleagues			
	often	*Sometime*	*Never*
Italian	8.41	63.48	28.11
Math	16.71	61.18	22.12
Attending online training courses			
	often	*Sometime*	*Never*
Italian	1.61	29.49	68.89
Math	2.53	37.21	60.25
Teach students how to use online encyclopedias			
	often	*Sometime*	*Never*
Italian	11.06	45.97	42.97
Math	9.22	21.43	69.35
Teach students how to use social network			

	often	*Sometime*	*never*
Italian	8.76	25.12	66.13
Math	2.53	19.93	77.53
Teach students about privacy			
	often	*Sometime*	*never*
Italian	1.96	2.76	95.28
Math	0	4.49	95.51
Use common software with students			
	often	*Sometime*	*never*
Italian	12.67	27.88	59.45
Math	31.45	37.1	31.45
Use specific software with students			
	often	*Sometime*	*never*
Italian	1.61	13.59	84.79
Math	17.74	29.38	52.88
Explain how to study with internet			
	often	*Sometime*	*never*
Italian	18.09	55.76	26.15
Math	17.05	38.25	44.7
Explain how to find groups in internet			
	often	*Sometime*	*never*
Italian	0	13.25	86.75
Math	2.07	4.49	93.43

Figure 1: Reading and Math test score distributions and within student difference.

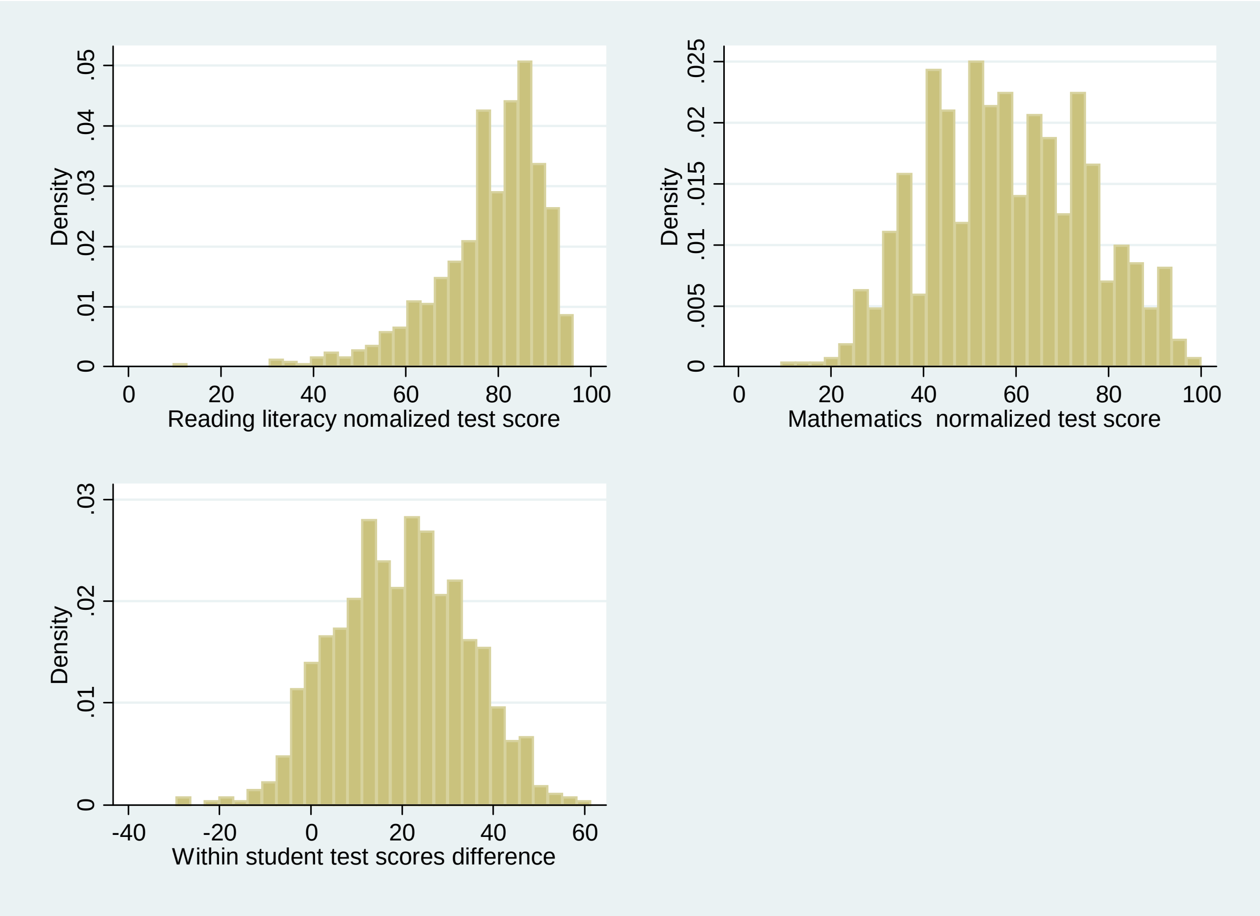

Figure2: Self-assessed and objective teachers’ ICT skills evaluation and their relation.