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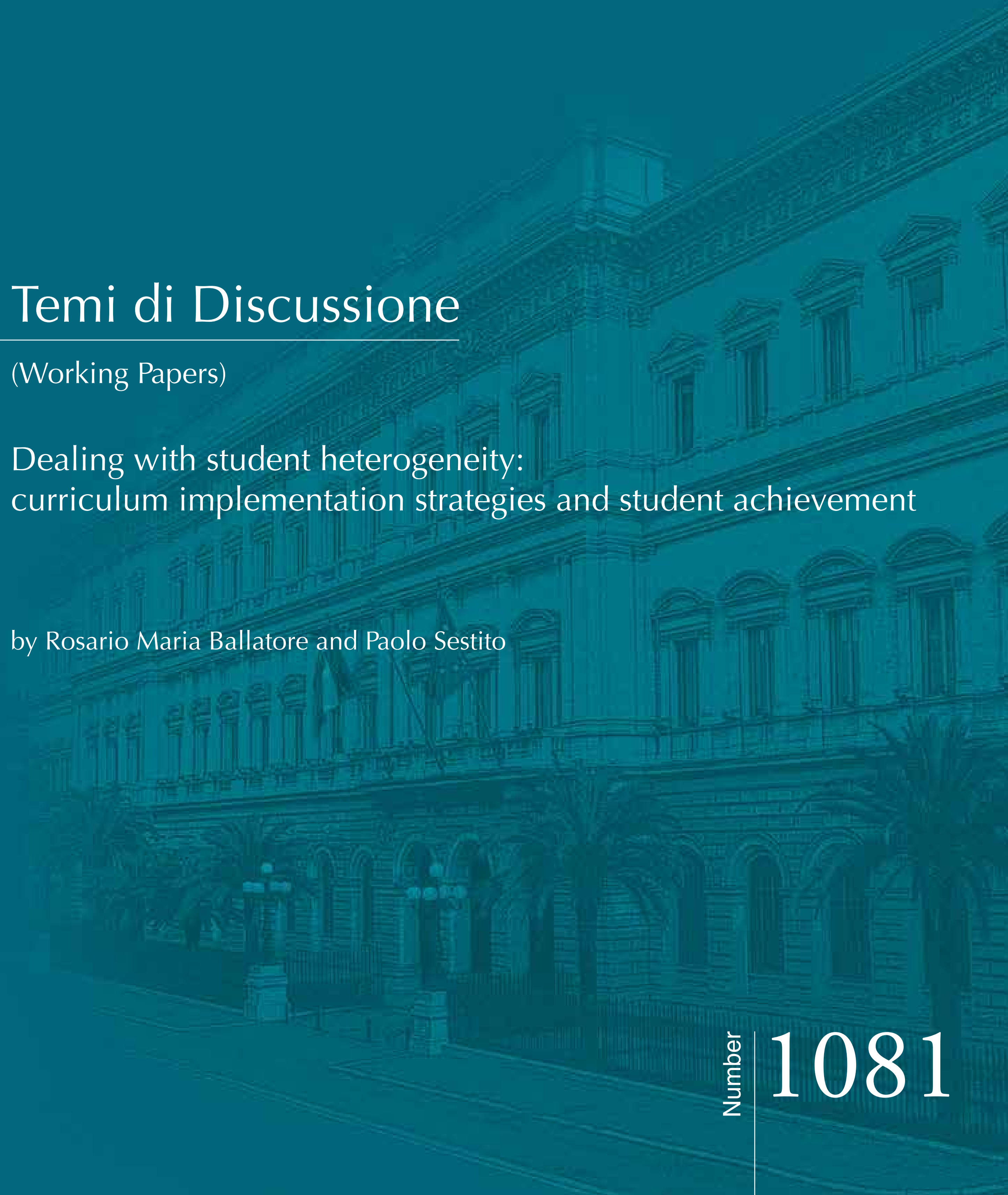

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DEALING WITH STUDENT HETEROGENEITY: CURRICULUM IMPLEMENTATION STRATEGIES AND STUDENT ACHIEVEMENT

by Rosario Maria Ballatore* and Paolo Sestito**

Abstract

In this study we investigate the relationship between student achievement and a crucial aspect of teaching: curriculum implementation strategies. More specifically, we consider three strategies representing teachers' approach in dealing with heterogeneous classes: i) spending time on the same topic until everyone understands, ii) moving on to another topic even if part of the class does not understand the previous one, and iii) spending time to revise concepts and topics already studied in the previous year. We exploit the within-student between-subjects variation in the frequency with which different teachers adopt each of the three strategies to control for constant student and class traits and for the possibility that teachers may adapt their strategies to class composition. Our findings show that spending time on the same topic until everyone understands is not associated with a better performance of less able students. On the contrary, it produces substantial achievement losses for the most able ones. Spending time revising topics studied in the previous year increases the achievement of less able students without lowering the performance of the most able ones.

JEL Classification: I21, I24, C33.
Keywords: student heterogeneity, curriculum implementation strategies.

Contents

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1 Introduction [1]

A vast body of the educational literature has focused on the role of teachers as one of the major determinants of students' achievement. The main goal of these studies has been the identification of effective teachers, i.e. teachers that produce sensible gains in students' learning, and, more importantly, which observable attributes are associated with effective teaching. Some of these studies evaluate the impact of teachers' demographic characteristics like gender or race (Dee, 2005, 2007), others focus on the role of experience, educational qualification or professional certification and training (see Clotfelter *et al.*, 2010; Kane *et al.*, 2008). However, most of these contributions reveal that these observable characteristics explain very little of the gains in students' achievement. Many other studies go beyond the identification of which specific teachers' characteristics affect students' performance. Using repeated observations of students for the same teacher, these contributions treat teachers' effectiveness as a fixed effect (see Aaronson *et al.*, 2007; Rivkin *et al.*, 2005; Rockoff, 2004). They conclude that unobserved teachers' characteristics explain much of students' achievement gains. Moreover they find that these unobserved factors are weakly related to the observed teachers' traits. These studies provide informative and rigorous evidence on overall teachers' quality, but they remain uncertain on what effective teaching actually is. In order to answer this question, a very recent body of the literature investigates the role of teaching process, shifting the focus from teachers' observed attributes to what they do in the classroom (Aslam and Kingdon, 2011; Lavy, 2011; Schwerdt and Wuppermann, 2011). These contributions go directly into the root of the educational production function by studying the effect of different teaching methods on students' learning. In particular, they contrast *traditional* teaching practices such as frontal lecturing and acquiring knowledge through memorization with *modern* practices like fostering critical thinking through problem solving, teachers-student interactions and group working. Despite most of the teaching reforms proposed in the U.S. discourage the use of traditional methods in favor of modern teaching practices, the empirical evidence that emerges from these studies support the idea that traditional teaching is commonly associated with higher students' achievement, and that some

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[1] We would like to thank Matteo Bugamelli, Alfonso Rosolia, Roberta Zizza, Andrea Lamorgese, Eliana Viviano, Effrosyni Adamopoulou, Francesco Manaresi, Francesco D'Amuri, Marco Paccagnella, Marco Tonello, Francesca Carta and two anonymous referees for their helpful comments. The views here expressed are those of the authors and do not necessarily reflect those of the Bank of Italy.

modern practices have beneficial effects only on the most able students.

In this paper we contribute to the literature on classroom teaching process by studying other crucial aspects of *teaching technology.* More specifically, we evaluate the impact of three teaching strategies on Italian sixth graders' achievement. These are: *i*) remaining on the same topic until everyone understands (hereafter T1), *ii*) moving on to another topic even if part of the class didn't understand the previous one (T2), and *iii*) revising topics already studied in the previous year (T3). Differently from the teaching strategies that have already been addressed in the recent literature, these practices go beyond the dichotomy *modern* vs *traditional.* They rather reflect the attitude of teachers in dealing with heterogeneous classes. In particular they represent how teachers advance the curriculum when students have different rates and methods of learning. Using the terminology of the educational literature we label these practices as *curriculum implementation strategies.*

The effects these strategies produce on students' learning are particularly worth to be explored especially in schooling systems where formal tracking of students (i.e. separate classrooms and curriculum for talented and non talented students) is not allowed, and teachers may deal with very heterogeneous classes. In a tracked schooling system teachers can calibrate the lessons to a more homogenous group of students, without worrying to meet everyone's educational needs. On the contrary, in a non tracked system, an efficient optimal practice may not exist and teachers often adopt these strategies on the basis of their preferences. For example, some teachers may prefer to address the needs of the less able students of the class trying not to leave anyone behind. This is case of a teacher who makes sure that everyone has grasped the topic explained before moving forward. Others may target their lessons on the needs of the top students avoiding losing time on the same topic to not compromise the learning process of the most able students. Additionally, in order to avoid frequent interruptions related to the difficulty in understanding the content of the lesson, some teachers may take some time to go over the topics studied in the previous year. Finally, it is noteworthy to know that these strategies are not necessary alternative options: teachers for istance can choose a mix of the three practices, trying at their best to get the most the class involved.

Educational literature on curriculum implementation strategies has long highlighted the benefits and disadvantages of each practice under scrutiny. Remaining on the same topic until everyone understans should in principle increase motivation and performance for the bottom students of a class. At the same time the effect on the most able pupils could be very detrimental, as their engagement vanishes as the lesson pace slows down (see Sangster, 2007). *Viceversa*, although moving on to another topic even if the previous one is unclear for part of the class should keep motivated the most able students, it could also increase the achievement inequality within the class. Revising topics already studied may reflect the willingness of the teacher to create the conditions so that everyone understands the new contents, but its effects on overall achievement remains ambigous.

This paper tries to empirically evaluate the effects that each of these strategies produce on average performance as well as on achievement gains (or losses) along students' ability distribution. Despite the fact that there is a wide body of educational literature that stresses the importance of these teaching strategies for students' performance, and the fact that they are a low-cost policy intervention (i.e. with respect to class size reductions), no empirical study on this argoument exists.

We fill this gap using the microdata on Italian sixth graders' achievement collected by INVALSI in the academic year 2009-10. A very detailed student questionnaire allows us to construct proper measure of the frequency at which teachers endorse a particular strategy. Estimating the effect of each of these strategies on students' learning arises a number of empirical issues connected with the endogeneity of teaching technology, since both students and teachers sort across schools and classes on the basis of ability and preference for a given instructional method. Moreover, teachers endogenously adapt their strategies to the level and the heterogeneity of the class. To minimize these problems we exploit the within-students subject-to-subject variability in the strategies. We find that the first two strategies (e.g. remaining on the same topic and moving on even if someone did not understand) are associated with lower students' performance on the average. Particularly, the first practice is not associated with better performance of less able students, and it produces losses of achievement for the most able ones. The second strategy instead reduces students' learning at each point of their ability distribution. Finally, we find that spending time on revising increases on average the achievement of less able students without lowering the performance of those who are more able. These results hold after several robustness checks.

While the within student subject-to-subject approach allows us to control for every unobserved student, school and class fixed traits, the selection of teachers with different unobservable attributes into different teaching method remains an issue and the estimated parameters may partially reflect a general teaching style rather than those strategies. Therefore we avoid to formulate policy conclusions that call for a specific teaching practice with respect to another and we simply present the results as the effect of the strategies that is not driven neither by the between and within school sorting of students nor by non random assignment of teachers to classes or by any endogenous adaptation of teachers to a given class composition.

This paper is structured as follows: in the following section we present the data. Section 3 describes the estimation strategy. Results are discussed in section 4. Section 5 presents some robustness exercises. Section 6 concludes.

2 Data and measurements

The analysis conducted in this paper are based on micro-data of Italian lower-secondary students in the academic year 2009-2010 provided by the National Institute of Educational System (INVALSI). Every year INVALSI tests the skills of pupils through a wide set of multiple choice questions. These questions measure grammatical, textual and lexical skills for the reading test, and the ones with numbers, geometry, functions and principles of data and statistics for the math. It is important to note that even if these questions are designed to test skills, without following necessarily the curriculum [2], it goes without saying that the curriculum coverage at the time of the test will improve the chances of doing well.

Starting from 2009-2010, the entire population of 2nd, 5th and 6th graders has been surveyed. In this paper, however, we limit the analysis to 6th graders, as the key information on teaching curriculum implementation strategies is only available for this grade. The testing procedure is held during the second half of the year and it consists of a two-hours examination (one hour per subject). More importantly, and differently from the testing procedure in primary schools, lower secondary students are required to take the reading and mathematics tests within the same day. This feature of the procedure minimizes the likelihood of observing missing values in one of the two subjects and mitigate any strategic absence from school driven by the relative goodness in a subject compared to the other. The test scores provided within the dataset are expressed as the percentage of correct answers that we standardize with

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[2] For further details on how students' questions are constructed see INVALSI (2010b)

respect to the mean achievement at national level in reading and mathematics to facilitate the interpretation of the results[3].

The dataset is fairly rich. Besides test scores, it collects information on a large number of socioeconomic indicators of each student and his/her family. The key variables of interest for this paper are derived from a very rich student questionnaire administred at the end of the testing procedure.[4] Thanks to this questionnaire students provide information on several aspects of their life both outside and inside the school, including their perception of teachers' practices in class. We derive our measure of curriculum implementation strategies from three different questions. In particular, students are asked to report how often a teacher of a given subject *i)* remains on the same topic as long as everyone understands, *ii)* moves on to the another topic even if not all of the students understood the previous one, *iii)* spends time to revise topics studied in the previous year. The possible answers to these questions are reported on four level categorical scale: 1=*never*, 2=*rarely*, 3=*often* and 4=*always*. We report distributions of students' answers, both uncontitional and within each couple of variables in tables A–1-A–4 of the Appendix. As the questionnaire asks the student to report the frequency with which each teacher endorses a particular strategy, it seems reasonable to us to treat these variables as cardinal by assigning proportional values to each categorical response: never=0, rarely=0.33, often=0.66 and always=1. Each of these variables averaged at class/subject level represents the focus of our analysis. In addition, as a robustness check we perform our empirical analysis by using a non linearization of the three teaching variables: in particular we use four dummies per strategy, one for each quartile of the variables: the results are qualitatively the same.

We carry out the analysis on a restricted sample of students for which we have information on both reading and math test scores. Given that the two tests were administred on the same day, we do not lose much information when we impose this restriction. Moreover, not not all students completed the questionnaire: the missing information in students' answers to questions related to teaching practices could make our main variables less reliable when they are aggregated at class level. In order to deal with this problem we drop from the

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[3] Final scores have mean 0 and a unitary standard deviation within each subject so that the results are interpretable as a fraction of a standard deviation.

[4] To get further information on the questionnaire administred to students see INVALSI (2010a).

sample the classes in which less than 80 percent of students return the questionnaire.[5] This further restriction makes us lose about 18 per cent of the total observations, however the general representativness of the sample do not seem compromised.[6] The final estimation sample consists of more than 352,000 students, 15,397 classes and 4,937 schools. Tables 1 summarizes the main variables of our analysis. Panel A and B display the test scores and other class-subject characteristics like mid term school marks and their distribution within the class. These data highlight the widely stated fact that Italian students perform better in reading than in mathematics while the dispersions of scores both overall and within a class is higher in mathematics. Panel C reports the class constant traits like class size, the index of social and cultural background (ESCS) an the share of immigrant students in classes. Table 2 provides brand new insights on the strategies endorsed by teachers in implementing the curriculum. First, the average teacher tends to remain on the same topic when students do not understand. Second, teachers spend considerable time to revise topics previously studied. Third, very rarely teachers move on to another topic even if not all students understood the previous one. Futhermore, teachers tend to remain on the same topic more frequently in mathematics than in reading. Table 4 shows the correlation between the three strategies. As we would expect, the correlation between strategies T1 and T2 is negative and highly significant. The magnitude of the correlation (around -0.24) shows that the two strategies are not perfectly substitutable. Strategies T1 and T3 tend instead to be complementary to each other: this means that teachers who spend time to revise topics already studied in the previous year also don't tend to introduce new concepts to the class if part of it did not understand the previous ones. These patterns emerge even when we plot the pairwise distribution of curriculum implemetation strategies by four intervals of adoption's intensity. Table 5 displays the share of teachers adopting the T2 strategy with a given intensity by intervals of the adoption of the practice T1: over 98 per cent of teachers that use intensively the strategy T1 (interval 4) adopt the strategy T2 very rarely (intervals 1 ad 2). At the same time, the degree of substitutability between these two strategies is weakened by the fact that most of the teachers that endore rarely the strategy T1 do the same with the strategy T2,

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[5] When we compute the percentage of students that return the questionnaire we consider all the students enrolled in the class, not just the ones who are present on the day of the test.

[6] Basically we compare the composition of our sample with the one randomly selected by INVALSI. In terms of geographical distribution, school and class size, percentage of lower background students at school, the two sample are very similar. These statistics are available upon request to the authors.

making them in some sense complementary at low intensity of adoption. In tables 6 and 7 we report the pairwise distributions between T1-T3 and T2-T3, showing that the highest share of teachers who adopt intensively the T3 strategy is among those who practice the T1 strategy with high levels of intensity and among those with low intensity of the T2. These simple exercises highlight the fact that the three curriculum implementation strategies are not mutually exclusive, and more combinations of them are possible. This is why we need to carry our analysis by considering the whole mix of strategies by looking at the effect of increasing the intensity of adoption of a pratice for a given level of adoption of the others. Finally, table 8 shows that the practices endorsed by teachers are sistematically correlated with many class characteristics. In particular, teachers tend to spend more time on the same topic or revising things already studied if there are more early-entrance students, probably because they need more attention. Similarly, teaching in classes with high proportion of students at the tails of mid term school marks distibution requires a more intense adoption of strategies T1 and T3 and lower level of the practice T2. On the contrary, an high proportion of non native students in the classroom makes teachers more prone to move on to another topic even if someone did not understand and to spend less time on the same topic or revising the ones already studied, maybe because immigrants' students do not ask a lot attention even though they would need it. These evidence suggest that the sorting of students and teachers, or the endogenous adaptation of teaching practices to the class traits could be an issue when we try to estimate the effect of the strategy under scrutiny on students' performance.

2.1 Measurement issues

The idea that students can characterize teachers' strategies in the classroom arises a number of issues and methodological problems about measurement. Several numbers of studies on teaching practices and classroom climate recently relied on this approach (see Lavy, 2011) and organizations like *Bill and Melinda Gates Foundation* recently used pupils' perception of teaching strategies with the attempt to evaluate the impact of different teaching strategies on students' value added. Other contributions rely on the availability of international data like TIMMS or PIRLS to construct their measures of instructional practices based on teachers' direct response to a questionnaire (see Aslam and Kingdon, 2011; Schwerdt and Wuppermann, 2011). Even if these measures are based on a single precise answer they may suffer from other problems. Teachers, for example, can overreport the time they report to spend with a particular instructional practice, or, *viceversa*, they can underreport the time spent on practices that are generally considered not worthy for children learning, even if they actually spend a lot of time on them.

The main concern in using student-reported teaching practices relies on the fact that individual perceptions may depend on students own ability. If this is the case, the perceived teaching practices would reflect unobserved individual factors rather than the true practice endorsed by the teacher. With these considerations in mind, we want to test the validity of our student-reported teaching practices before moving on to the empirical analysis. One option would be to check if there is coherence in the perception on teaching strategies between the single student and his or her classmates. An evidence of students' perception converging towards class perception would signal that students' perception does not depend much on individual characteristics (such as the ability or relative position with respect to the class) but is instead the true perception of what teachers are doing. Table 9 shows the results of a regression where the dependent variable is the student perceived practice (T1, T2 and T3) and the covariates are the class average perception - excluding student's own answer. We run these regressions with simple OLS (Panel A) and conditioning to the students fixed effect (Panel B). In both specifications the results point to a very high coherence between student and class average perception, suggesting that our student-reported variables can be considered accurate measures of what actually happens in the classroom[7]. In addition, in the robustness section we check the validity of our results to the definition of our teaching strategies variables using more homogeneous groups of students within a class.

3 Empirical analysis

To estimate the effect of the three different strategies on students' achievement we start by considering the standard education production function:

$$y_{ijck} = \alpha_j + X'_{ick}\beta + T'_{ijck_{-i}}\delta + \varepsilon_{ijck} \tag{1}$$

where the normalized test score, y_{ijck}, of student i in subject $j \in [read, math]$ in class/school ck is related to student, class and school characteristics (X'_{ick}) and to a vector of class level

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[7] Note that even if this correlation might also reflect the fact that students' beliefs within a class influence eachother, we believe that perceptions about teaching practices are less prone to be influenced by peers, as they are easily detectable by students.

curriculum implementation strategies ($T'_{ijck_{-i}}$). As already stated in the previous sections, this paper focuses on three different teaching strategies, namely: T1 the time a teacher dedicates to allow every single student to grasps a given topic, T2 the time a teacher moves on to another topic even if not all students understood the previous one and T3 the time spent to revise topics previously studied.

The main concern in estimating the impact of teaching strategies on educational outcome is that their effects may be confounded by correlated unobserved factors also directly related to students' performance. Formally, this is equivalent to say that the error term of equation (1) contains the following unobserved components:

$$\varepsilon_{ijck} = \nu_i + \mu_c + \theta_k + \tau_{jc} + \epsilon_{ijck} \tag{2}$$

where ν_i, μ_c, θ_k and τ_{jc} are respectively the individual, the class, the school and the teachers unobserved characteristics, while ϵ_{ijck} is the idiosyncratic error term. There are several reasons suggesting that a correlation between these unobserved components and teachers' curriculum implementation strategies could arise. First, if teaching practices are partially determined by the school policy and parents place their children on the basis of their ability in schools that promote a particular instructional practices. This is the case in which parents try to place their high achieving children in schools where teachers spend less time on the same topic, or when *viceversa* parents of less able students place their children in schools that support instructional practices best suited to meet their educational needs. Second, both the class formation process and the assignment of teachers to the classrooms are not random. In addition, even if students are randomly assigned, teachers could endogenoulsy adapt their instructional practices to the level of the class or its composition. Because of these underlying selection mechanisms, any attempt to estimate the equation (1) by OLS would produce inconsistent estimates of the causal population regression parameters δ.

In this paper we try to minimize these bias by exploiting the within-student, subject to subject variation in the strategies endorsed by teachers. This approach was proposed by Aslam and Kingdon (2011) and by Schwerdt and Wuppermann (2011) to estimate the effect lecture style teaching method on students' achievement, and applied by Lavy *et al.* (2012) in a study on ability peer effects. Note that while most of these studies exploit the within student variation in an institutional context where classmates change between subjects, in the Italian schooling system classmates are fixed and do not vary between subjects. We believe that this would represent an improvement with respect to these previous studies.

More formally, we use the fact that we observe data on student test scores and teaching strategies both in reading and mathematics to take the first differences of equation (1):

$$\Delta y_{ick} = \Delta T'_{ick_{-i}}\delta + \Delta\tau_{ck} + \Delta\epsilon_{ick} \tag{3}$$

Note that one advantage of this approach is that every student, class and school constant traits are absorbed by student fixed effects. Therefore, looking at the within student variation of teaching strategies and test score implies that our estimates are no more biased neither by the sorting of students among schools nor by non random classroom assignment of students and teachers or by endogenous adaptation of teaching strategies to the level of the class. A crucial assumption of this approach relies on the fact that students' unobserved characteristics are subject invariant. The assumption that the subject specific component of students' ability is negligible when one accounts for the students' fixed effect is standard in this literature. Given that we do not observe in the data a direct measure of students' subject specific ability, such as the previous test score performance, we cannot test this assumption. However, we can look at the sensitiveness of our results when we include in the regression two subject specific characteristics such as mid term school marks[8] and a distribution measure like their skewness. Additionally, as a robusteness check, we include in the regression many class fixed traits interacted with the subject dummy to control for the asymetric effects that these characteristics may have on students' performance and, at the same time, on teaching practices endorsed by teachers in the two subjects.

Before going to the results, three further remarks are worth noting. First, one necessary assumption needed in our identification strategy is that the effect of different teaching strategies on students' achievement is the same across subjects (see Dee, 2005, 2007)[9] Second, correct identification of the parameters of interest requires that the effect of each teaching strategy does not spill over between subjects, e.g. remaining a lot of time in a given topic allowing everyone to understand it in reading (high level of T1) does not have any effect on math

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[8] At individual level we use the mid term school marks in mean deviation with respect to the class average. As robustness we use the average mid term school marks at class level. However this latter control may also reflect the teacher grading practice rather than the class subject specific ability.

[9] As a robustness check we do however estimate a version of equation (3) where we relax the assumption of equality of the effects in the two subjects.

performance.[10] Finally, note that equation (3) still contains the term $\Delta\tau_{ck}$, i.e. the difference in the unobserved characteristics between reading and math teachers. As we are not able to get rid of this term from equation (3) we cannot give a causal interpretation to our estimated coefficients, as long as these unobservable traits are correlated with the instructional strategies endorsed by teachers (i.e. we cannot distinguish the effect of the teaching practices from teachers' general effectiveness). We therefore interpret the δ coefficients as the correlation between curriculum implementation strategies and students' performance that is not driven neither by the between and within school sorting of students nor by non random assignment of teachers to classes or by any endogenous adaptation of teachers to a given class composition.

4 Results

Table 10 reports estimates in which the dependent variable is the standardized test score and the key variables of interest are the three curriculum implementation strategies. In each regression the unit of observation is the single student, while the teaching practices are at class level[11]. In each column the standard errors are clustered at class level to correct for colleration of residuals within classes. Column 1 reports results from estimating equation (1). Column 2 adds to the specification the school fixed effects to get rid of the bias coming from the sorting of students and teachers among schools. Both specifications are estimated in the pooled sample of reading and math and the subject fixed effect is also taken into account. Though not reported in the table, these regressions include the full set of individual and class controls. The estimated results show that both T1 and T2 practices have a negative and sizeable effect on students' achievement, while T3 strategy is estimated to have a positive impact on learning. As discussed in the previous section, these results may be confounded by the sorting of students and teachers among and within schools and by the endogenous adaptation of teaching practices to class level and composition.

Columns 3-5 report the estimate of equation 3 where all the individual, class and school

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[10] Note that in our framework the treatment is at class level and interactions between students within a class are not sufficient to invalidate the SUTVA. When classes are the treatment units, this hypothesis is violated when there are interactions between them. More specifically, given the presence of students' fixed effects in our estimated equation, the assumption needed to preserve the SUTVA is the absence of spillover effects between subject.

[11] The class averages of each of the three strategies are computed excluding each student's own answer.

fixed traits are differenced out by the inclusion of the pupil fixed effect. To begin with, column 3 reports the estimates of a specification that includes the subject fixed effect and its interaction with the gender and immigrant status dummies to capture the well stated facts that male and immigrants tend to perform relatively better in math than in reading. Then, we include the individual mid term school marks in reading and math (column 4), and their skewness to control for the possibility that teachers may adjust their strategies according to the distribution of subject specific abilities within a class (column 5). These estimates confirm that both T1 and T2 strategies have a negative and significant impact on test scores but the magnitude of the effects was markedly reduced with respect to those reported in columns 1-2. We interpret these results as an evidence that a considerable bias exists when student fixed effects are not taken into account. The coefficient of the time a teacher spends to revise topics studied in the previous year (T3) continues to indicate a positive impact on students' achievement. The magnitude of the coefficients is quite small. Looking at our headline specification (column 5) the point estimates suggest that an increase of 10 percentage points in T1 and T2 (roughly 1σ in these strategies distribuitions) reduces the test scores respectively by .010 and .016 a standard deviation. The positive effect of increasing by the same amount the T3 strategy (=1,25 a standard deviation) is about $.016\sigma$ of the test score distribution. Interestingly, the results displayed in columns 3-5 show that the point estimates do not change significantly across specification, even when we add the subject specific controls. This is reassuring because once we condition for the overall student fixed effect there is no others students' subject specific factors that could virtually bias our estimates.

The previous findings suggest that two of the three strategies in implementing the curriculum have negative effects on students' achievement. In particular we obtained the same negative results for two strategies that tend to be negativelly correlated (e.g. T1 and T2). We believe that this is not surprising as both strategies implicitly focus on different specific segment of the class population. Given that classes are rarely homogeneous in terms of students' ability, these strategies could on one hand have beneficial effects for the group of students they address, and on the other hand be detrimental for students they don't take into account. The resulting average effect depends on the magnitude of the achievement gains obtained by the addressed students compared to the size of losses in achievement of the students not taken into account by the strategy. Our results show that the losses generated endorsing both T1 and T2 stategies are much higher than the possible beneficial effects for those pupils they are addressing. In this sense neither strategies should be considered optimal to be endorsed as long as classes are not homegeneous. On the contrary, spending time to revise topics already studied in the previous year efficiently increases the average test scores.

To get further insights on how these strategies differently affect students' achievement in different segments of the ability distribution, we estimate equation 3 splitting the sample according to the relative position of each student with respect to his or her classmates. We use the mid term school marks averaged across subjects (taken in mean deviation from the class average) to stratify the sample in five non overlapping quintiles. Results are displayed in table 11. Each column shows the estimated coefficients for the three strategies across the quintiles of the relative ability distribution. The findings give detailed explanation of the results previously discussed and provide interesting information on winners and losers of each of the three strategies adopted by teachers. Surprisingly, remaining on the same topic until everyone understands does not increase achievement of less able students, while it reduces significantly the performance of the most able ones. In this sense, besides reducing the performance of the most able students of the class, this strategy fails to be effective in improving learning of those students who intended to motivate. On the contrary, moving on to another topic even if someone did not understand, uniformely reduces the students' test score in every segment of the ability distribution. Finally, spending time to revise topics has a strong positive effect on students' achievement in the bottom part of the distribution. More importantly, these achievement gains do not come at any expense of the most able students' learning.

5 Robustness

In this section we present different robustness exercises. We start by testing the sensitivity of our results with the insclusion of other class level controls. This exercise is motivated by the concern that unobserved factors like students' ability may be not fixed through subject. If this is the case, the effects of the teaching variables would be partially driven by the correlation between the class subject specific traits and the practices endorsed by teachers. Table 12 shows the coefficients of the three teaching strategies when we add to the regressions other subject specific controls. These are: the average mid term school marks, their standard deviation and their kurtosis. The coefficients of the three strategies remain fairly stable when we add these controls. As a further robustness check we add to our main specification several class fixed characteristics like the average ESCS and its standard deviation, the class size, the share of immigrant students, the share of female students, the share of retained students and the percentage of early entrance pupils in the class. All of these controls are interacted with the subject dummy. Even if the class composition does not change through subjects, such characteristics may affect in a different way the students' achievement in reading and math. For istance, pupils with a low level family background may perform better in mathematics than in reading as the family background is likely to have a stronger influence on the reading performance. These asymetric effects may introduce subject specific traits, even when the classes are fixed through subjects. Table 13 reveals that including these class characteristics change only marginally the magnitude of teaching practices coefficients. In particular, looking at the richest specification in column 4, T1 and T2 coefficients pass from -0.10 and -0.16 to -0.12 and -0.17, while the effect of the strategy T3 falls only by 3 percentage points. The results presented so far in tables 12 and 13 are therefore quite reassuring as they did not provide any strong evidence in favor of a subject specific unobeserved factors biasing dramatically our estimates: when we control for student fixed effect there is no others subject specific factors that may bias our estimates.

Another concern when we use student-reported measures of teaching practices is that these perceptions may be biased by the individual own ability, both in absolute terms and with respect to the class average. In section 2.1 we already checked the validity of our measures by looking at the coherence between individual and class' perception. As a further check we now estimate equation (3) by averaging the students' perception of the teaching practices in sub-groups of homogenous individuals within classes. This control is motivated by the fact that students' ability may bias the perceptions of a teacher endorsing one of the three practices under scrutiny. Particularly, low achiever students may report a small frequency at which the teacher endorses strategy T1 and T3, while they could perceive a more pronounced endorsement of strategy T2. By using the average perception on sub-groups of more homegeneous students both in reading and math we test the sensitivness of our results with respect to this concern. Column 1 of table 14 reports the results when we use only the perception of low-achiever students, i.e. students with mid term school marks below the class average. In column 2 we use the perceptions of the high achievers, while column 3 reports the results when we use the low achievers perceptions only for T2 strategy and the high achievers perceptions for T1 and T3. Although the magnitude of the coefficients are partially reduced the results are qualitatively confirmed. Results are confirmed even if we change the way we compute our teaching practices variables. Indeed, when we perform our analysis using a set of dummies, one for each quartile of the variables (see table 15), the estimated parameters tell the same story: both T1 and T2 reduce the achievment, while the T3 strategy increases students' learning. In addition, the table shows that the effects come from high intensity in the adoption of the strategies.

In table 16 we estimate a version of the equation (3) where we relax the assumption that the cofficients of our three teaching practices are equal in the two subjects. Particularly, we estimate the equation:

$$\Delta y_{ick} = (y_{ick[read]} - y_{ick[math]}) = T'_{ijck_{read-i}}\delta_{read} - T'_{ijck_{math-i}}\delta_{math} + \Delta\tau_{jck} + \Delta\epsilon_{ick} \qquad (4)$$

Given that all math coefficients enter negatively on both sides of the equation (4), positive estimated parameters for the the teaching variables in math imply a negative correlation between the variables and the test scores in mathematics. At the same time, a negative coefficient masks a positive relationship with the performance. The results show that all the coefficients have the expected sign. Moreover, we found that spending more time on the same topic reduces the performance more in math than in reading, while moving on to the next topic has an higher negative effect in reading. We have some heterogeneity even in the effect that the strategy T3 produces on student performance, with the one in math being positive but smaller than the one observed in reading.

In the last set of robustness exercises we test the validity of the results presented in table 11, i.e. the heterogeneous effects by students' relative ability. First we try other possible way to rank the students. Table 17 reports the results on the five quintiles using three other ranking methods: using students' average mid term school marks standardized with respect to the class mean and standard deviation (Panel A), based on the ratio between the individual average school mark and the class average (Panel B), and using average test score performance in mean deviation with respect the class average (Panel C). Finally, we test if the results presented in table 11 are not driven by the fact that pupils at the top or at the bottom of the ability distribution have some particular comparative advantage in one of the two subjects. In order to check if this is actually what is driving our quintile estimates we limit our analysis on a subsample of pupils that display low variability in the ability between subjects. In table 18 we consider only pupils with the standard deviation between mid term school marks in reading and math- taken in mean deviation from the class average - below the overall median value. In this way we restrict the analysis on pupils that are "equally" good or bad in both subjects. All of these estimates confirm the results presented so far: strategy T1 reduces the performance of more able pupils, though not increasing the achievement at the bottom of the distribution; strategy T2 reduces the performance at every point of the ability distribution and strategy T3 results in an increase of the performance of less able students without lowering the achievement of those students on the top of the ability distribution.

6 Conclusion

Most of the educational literature claims that teachers matter for students' achievement. However, observable teachers' traits are found to be bad predictors of teacher's quality. Recent studies shift the focus from teachers' characteristics to the teaching process, i.e. what they do in the classroom. Most of these papers contrast *modern* and *traditional* teaching strategies, supporting the idea that traditional teaching is commonly associated with higher students' achievement, with some of the modern practices having beneficial effects only on the most able students. In this paper we contribute to the literature on teaching process in the classroom by studying other crucial aspects of the *teaching technology*: curriculum implementation strategies. More specifically, we evaluate the impact of three strategies on Italian sixth graders' achievement: *i*) remaining on the same topic until everyone understands (T1), *ii*) moving on to another topic even if part of the class didn't understand the previous one (T2), and *iii*) revising topics already studied in the previous year (T3). We believe that these strategies reflect the attitude of the teacher in advancing the curriculum when students have different rates and methods of learning. We derive our measures of curriculum implementation strategies based on information provided by students in the 2010 wave of the INVALSI survey. Exploiting the within students, subject-to-subject variation to control for unobserved student and class fixed traits, we find that on average an increase of 10 percentage points in T1 and T2 (roughly 1σ in these strategies distribuitions) reduces the test scores respectively by .010 and .016 a standard deviation. These findings suggest that when classes are not homogeneous in terms of learning method and rate (as the Italian schooling system does not allow for ability tracking) teaching strategies that are mainly addressed to increase motivation and performance of a specific segment of the class population (like the T1 and the T2 strategy) are not efficient, since they lower the average performance of the class. We find however that T3 strategy is associated with higher students' performance: an increase of 10 percentage points (=1,25 a standard deviation) traslate into an shift of $.016\sigma$ of the test score distribution. When we focus on the winners and losers of each of the three strategies by looking at the effects that these practices produce in the achievement of students in different segment of the ability distribution we find that remaining on the same topic until everyone understands does not increase achievement of the less able students, while it reduces significantly the performance of the most able ones. In this sense, besides reducing the performance of the most able students of the class, this strategy fails to be effective in improving learning of those students who intended to motivate. On the contrary, moving on to another topic even if someone did not understand uniformely reduces students' test score in every segment of the ability distribution. Spending time to revise topics has a strong positive effect on students' achievement in the bottom part of the distribution. More importantly, these achievement gains do not come at any expense of the more able students' learning. We show that all these results are quite robust to the inclusion of additional subject specific controls, as well as to different definitions of teaching strategies and to different ranking methods of students' ability.

Our results should be considered carefully and should be interpreted as the association between curriculum implementation strategies and students' learning that is not driven neither by the between and within school sorting of students nor by non random assignment of teachers to classes or by any endogenous adaptation of teachers to a given class composition. We cannot fully exclude that the use of particular teaching methods is proxying for unobserved teacher's characteristics having an impact upon studentsâ learning. Notice that to the extent that teaching methods derive from teachers' characteristics, our efforts to purge form the endogenous adaption of teaching practices to the actual class composition are made easier, but the labelling of the effects could be misleading, as the teaching practices would be capturing the different teachersâ unobserved effectiveness. However, we believe that a *scenario* in which worst teachers systematically select into T1 strategies - driving down our results - is not consistent with the selection of the same teachers into a strategy that is found to be negativelly correlated with it (i.e. T2). At the same time, systematic selection of the worst teachers into T1 practice and a selection of high quality teachers into strategy T3 cannot cohesist, as T1 and T3 are positively correated. We can thus reasonably exclude that the signs of our results may be fully driven by some unoberserved teachers' characteristics. Even if additional research is needed in this field, we believe that this paper is relevant for the debate on optimal teaching process, expecially when some degree of heterogeneity within the classroom exists.

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Tables

Table 1: Descriptive statistics

	Reading		Mathematics	
	Mean	SD	Mean	SD
	Panel A. Test scores and school marks (Student-subject level)			
Test scores	0.614	(0.154)	0.518	(0.181)
Mid term school marks	6.60	(1.15)	6.66	(1.38)
	Panel B. School marks distribution (Class-subject level)			
(SD.) mid term school marks	1.02	(0.23)	1.26	(0.27)
(SK). mid term school marks	-0.097	(0.454)	-0.111	(0.422)
(KUR.) mid term school marks	0.59	(0.26)	0.60	(0.21)
	Panel C. Class characteristics (Class level)			
ESCS	0.04		(0.597)	
(SD.) ESCS	1.025		(0.272)	
Class size	22.9		(3.6)	
Share of immigrants	0.100		(0.106)	
Share of female students	0.484		(0.110)	
Share of retained students	0.068		(0.071)	
Share of early entrance students	0.013		(0.040)	
Observations				
Number of students:	352,529 (705,058 overall)			
Number of classes:	15,397 (30,794 overall)			
Number of schools:	4,937 (9,874 overall)			

Notes: The unit of observation is the student in a given subject in panel A, the class-subject in panels B, and the class in panel C. The mid term school marks are in a range of 1-10. Standard deviation in parentheses.

Table 2: Descriptive statistics; curriculum implementation strategies

	Reading		Mathematics	
	Mean	SD	Mean	SD
T1: Remain on the same topic until everyone understands	0.480	(0.104)	0.538	(0.094)
T2: Moving on to another topic even if someone did not understand	0.189	(0.093)	0.170	(0.091)
T3: Revising topics already studied in the previous year	0.572	(0.084)	0.569	(0.80)

Notes: The unit of observation is the class in a given subject. The teaching strategies variables are a class average of students' perceptions (in a range of 0-1). Standard deviation in parentheses.

Table 3: Unconditional distribution of curriculum implemetation strategies by interval of intensity

	Perceived T1: Remaining on the same topic until everyone understands	Perceived T2: Moving on to another topic even if someone did not understand	Perceived T3: Revising topics already studied in the previous year
$T \in [0, 0.25]$	0.71	78.24	0.10
$T \in (0.25, 0.50]$	44.66	21.09	19.39
$T \in (0.50, 0.75]$	53.41	0.63	78.96
$T \in (0.75, 1]$	1.22	0.04	1.55

Notes: Unconditional distribution of curriculum implementation stategies. Share of teachers that adopt the strategy with a given intensity. Pooled sample of subjects. Observations at class level.

Table 4: Correlation matrix among curriculum implementation strategies

Teaching strategies	T1	T2	T3
T1	1.000		
T2	-0.236***	1.000	
T3	0.330***	-0.152***	1.000

Notes: The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. Pooled sample of subjects. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Conditional distribution of teaching strategies: T1-T2

	T2 $\in [0, 0.25]$	T2 $\in (0.25, 0.50]$	T2 $\in (0.50, 0.75]$	T2 $\in (0.75, 1]$
T1 $\in [0, 0.25]$	39.22	48.28	12.07	0.43
T1 $\in (0.25, 0.50]$	74.32	25.02	0.66	0.00
T1 $\in (0.50, 0.75]$	85.21	14.57	0.21	0.01
T1 $\in (0.75, 1]$	88.62	10.84	0.00	0.54

Notes: Conditional distribution of strategies T1 and the T2, by intervals of intensity. Share of teachers that adopt the T2 practices with a given intensity on the total number of teachers adopting the T1 strategy for each interval of intensity. Pooled sample of subjects. Observations at class level.

Table 6: Conditional distribution of teaching strategies: T1-T3

	T3 $\in [0, 0.25]$	T3 $\in (0.25, 0.50]$	T3 $\in (0.50, 0.75]$	T3 $\in (0.75, 1]$
T1 $\in [0, 0.25]$	1.72	56.47	41.81	0.00
T1 $\in (0.25, 0.50]$	0.06	26.05	73.42	0.47
T1 $\in (0.50, 0.75]$	0.01	12.67	85.50	1.82
T1 $\in (0.75, 1]$	0.04	18.98	79.61	1.37

Notes: Conditional distribution of strategies T1 and the T3, by intervals of intensity. Share of teachers that adopt the T3 practices with a given intensity on the total number of teachers adopting the T1 strategy for each interval of intensity. Pooled sample of subjects aggregated. Observations at class level.

Table 7: Conditional distribution of teaching strategies: T2-T3

	T3 $\in [0, 0.25]$	T3 $\in (0.25, 0.50]$	T3 $\in (0.50, 0.75]$	T3 $\in (0.75, 1]$
T2 $\in [0, 0.25]$	0.04	16.92	81.62	1.43
T2 $\in (0.25, 0.50]$	0.03	26.50	72.38	1.10
T2 $\in (0.50, 0.75]$	1.14	55.68	42.05	1.14
T2 $\in (0.75, 1]$	0.00	25.00	25.00	50.00

Notes: Conditional distribution of strategies T2 and the T3, by intervals of intensity. Share of teachers that adopt the T3 practices with a given intensity on the total number of teachers adopting the T2 strategy for each interval of intensity. Pooled sample of subjects. Observation at class level.

Table 8: Correlation between curriculum implementation strategies and class characteristics

	T1: Remaining on the same topic until everyone understands	T2: Moving on to another topic even if someone did not understand	T3: Revising topics already studied in the previous year
ESCS (a)	-0.153***	-0.098***	-0.069***
(SD.) ESCS (a)	0.007***	-0.016***	-0.069***
Class size (a)	-0.029***	-0.016***	0.016***
Share of female students (a)	-0.025***	-0.089***	-0.022***
Share of immigrants (a)	-0.044***	0.115***	-0.044***
Share of retained students (a)	0.033***	0.141***	-0.047***
Share of early entrance students (a)	0.0280***	-0.052***	0.018***
Mid term school marks (b)	-0.176***	-0.176***	-0.035**
(SD.) mid term school marks (b)	0.148***	0.039***	-0.022***
(SK.) mid term school marks (b)	0.063***	0.059***	0.002**
(KUR.) mid term school marks (b)	0.005***	-0.008***	0.006***

Notes: The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. Pooled sample of subjects. (a) Class characteristics fixed through subjects. (b) Class characteristics subject specific. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 9: Individual and classmates perceptions of curriculum implementation strategies

	Perceived T1		Perceived T2		Perceived T3	
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A. OLS estimates			
T1: Remaining on the same topic until everyone understands	0.6869*** (0.003)	0.6701*** (0.003)		-0.0602*** (0.003)		0.0777*** (0.003)
T2: Moving on to another topic even if someone did not understand		-0.0583*** (0.002)	0.5946*** (0.004)	0.5745*** (0.005)		-0.0472*** (0.003)
T3: revising topics already studied in the previous year		0.0178*** (0.003)		-0.0316*** (0.003)	0.4411*** (0.005)	0.4006*** (0.005)
			Panel B. Within pupils estimates			
T1: Remaining on the same topic until everyone understands	0.7390*** (0.005)	0.7022*** (0.005)		-0.0946*** (0.005)		0.0537*** (0.005)
T2: Moving on to another topic even if someone did not understand		-0.1017*** (0.006)	0.6308*** (0.008)	0.5593*** (0.010)		-0.1001*** (0.007)
T3: Revising topics already studied in the previous year		0.0233*** (0.006)		-0.0654*** (0.006)	0.4092*** (0.010)	0.3491*** (0.011)
Observations	705,058	705,058	705,058	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variables are the individual perception of T1 (columns 1 and 2), the individual perception of T2 (columns 3 and 4) and the perception of T3 (columns 5 and 6). The teaching strategies variables are a class average of students' perceptions excluding the student's *i* own observation. OLS estimates in Panel A and pupil fixed effect in Panel B. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 10: Main results: the effect of curriculum implementation strategies on students' achievement

	OLS	School fixed effects	Within pupils estimates		
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)	(4)	(5)
T1: Remaining on the same topic until everyone understands	-0.5738***	-0.3184***	-0.1051***	-0.1072***	-0.1054***
	(0.024)	(0.019)	(0.031)	(0.031)	(0.031)
T2: Moving on to another topic even if someone did not understand	-0.5944***	-0.4286***	-0.1525***	-0.1642***	-0.1622***
	(0.027)	(0.022)	(0.038)	(0.038)	(0.038)
T3: Revising topics already studied in the previous year	0.1150***	0.0566**	0.1733***	0.1694***	0.1687***
	(0.030)	(0.024)	(0.043)	(0.043)	(0.043)
Subject (reading)			0.1357***	0.1163***	0.1164***
			(0.005)	(0.005)	(0.005)
Subject*gender (reading, male)			-0.2034***	-0.1635***	-0.1634***
			(0.004)	(0.004)	(0.004)
Subject*imm.status (reading, imm.)			-0.2401***	-0.2490***	-0.2489***
			(0.008)	(0.008)	(0.008)
Mid term school marks (mean dev.)				0.1766***	0.1766***
				(0.003)	(0.003)
Sk. mid term school marks					-0.0074
					(0.007)
Observations	705,058	705,058	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. Though not reported, columns (1) and (2) include other individual and class level controls like: a gender dummy, a dummy signaling the immigrant status, the index of economic, cultural and social background (ESCS), a dummy for retained students, a dummy for early enrolled students, the average ESCS at class level and its standard deviation, the class size, the share of immigrants and female students, the share of early and retained students. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 11: Main results: the effect of curriculum implementation strategies on students' achievement; breakdown by pupils' ability

	Within pupils estimates		
	T1: Remain on the same topic until everyone understands	T2: Moving on to another topic even if someone did not understand	T3: Revising topics already studied in the previous year
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)
a) Effects for percentiles below 20	-0.0515	-0.1271**	0.2793***
	(0.047)	(0.057)	(0.066)
b) Effects for percentiles 20-40	-0.0193	-0.1789***	0.1543**
	(0.049)	(0.060)	(0.067)
c) Effects for percentiles 40-60	-0.1222**	-0.1254**	0.1753***
	(0.050)	(0.067)	(0.069)
d) Effects for percentiles 60-80	-0.1439***	-0.1391**	0.0943
	(0.048)	(0.059)	(0.066)
e) Effects for percentiles above 80	-0.1650***	-0.2076***	0.0748
	(0.045)	(0.056)	(0.062)
Test for equality of coefficients (p-value)			
H_0: b=a	*0.97*	*0.45*	*0.15*
H_0: c=a	*0.27*	*0.95*	*0.24*
H_0: d=a	*0.09*	*0.89*	*0.04*
H_0: e=a	*0.04*	*0.25*	*0.02*

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. The percentiles are defined ranking each student on the basis of his/her across-subjects average of mid term school marks taken in mean deviation with respect to the class average. The specification includes the full set of controls of column (3) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 12: Robustness: the effect of curriculum implementation strategies on students' achievement; additional class-subject controls

	Within pupils estimates		
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)
T1: Remaining on the same topic until everyone understands	-0.1057*** (0.031)	-0.1050*** (0.031)	-0.1050*** (0.031)
T2: Moving on to another topic even if someone did not understand	-0.1628*** (0.038)	-0.1626*** (0.038)	-0.1628*** (0.038)
T3: Revising topics already studied in the previous year	0.1689*** (0.044)	0.1677*** (0.044)	0.1677*** (0.044)
Avg. mid term school marks	-0.0007 (0.008)	-0.0003 (0.008)	-0.0003 (0.008)
Sd. mid term school marks		-0.0068 (0.013)	-0.0067 (0.013)
K. mid term school marks			-0.0045 (0.011)
Observations	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. All the specifications include also the full set of controls of column (5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 13: Robustness: the effect of curriculum implementation strategies on students' achievement; additional class controls

	Within pupils estimates			
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)	(4)
T1: Remaining on the same topic until everyone understands	-0.1212***	-0.1214***	-0.1214***	-0.1200***
	(0.031)	(0.031)	(0.031)	(0.031)
T2: Moving on to another topic even if someone did not understand	-0.1792***	-0.1793***	-0.1790***	-0.1777***
	(0.037)	(0.037)	(0.037)	(0.037)
T3: Revising topics already studied in the previous year	0.1371***	0.1373***	0.1376***	0.1348***
	(0.043)	(0.043)	(0.043)	(0.043)
ESCS*subject (reading)	0.0526***	0.0528***	0.0534***	0.0531***
	(0.007)	(0.007)	(0.007)	(0.007)
Sd.ESCS*subject (reading)		0.0048	0.0048	0.0040
		(0.015)	(0.015)	(0.015)
Class size*subject (reading)			-0.0005	-0.0004
			(0.001)	(0.001)
Share imm.*subject (reading)				0.0850**
				(0.036)
Share female*subject (reading)				0.0405
				(0.033)
Share retained*subject (reading)				-0.0598
				(0.059)
Share early entrance*subject (reading)				-0.0555
				(0.120)
Observations	705,058	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. All the specifications include also the full set of controls of column (5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 14: Robustness: the effect of curriculum implementation strategies on students' achievement; alternative measures of teaching practices

	Within pupils estimates		
Dependent variable: 6_{th} graders test score (standardized)	Only low achiewers perceptions (1)	Only high achievers perceptions (2)	Mixed (3)
T1: Remaining on the same topic until everyone understands	-0.0427* (0.0249)	-0.0854*** (0.0267)	-0.0532** (0.0255)
T2: Moving on to another topic even if someone did not understand	-0.0619** (0.0279)	-0.1561*** (0.0312)	-0.0682** (0.0277)
T3: Revising topics already studied in the previous year	0.1071*** (0.0305)	0.0966*** (0.0331)	0.1134*** (0.0329)
Observations	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. In column (1) we compute the teaching variables averaging only the low achievers' perceptions, while in column (2) we use only the perceptions of high achievers. In column (3) we compute T1 practice using only high achievers' perceptions, T2 practice using only low achievers' perceptions and T3 variable averaging only high achievers' perceptions. Low achiever students are those with mid term school marks below the class median. All the specifications include the full set of controls of column (5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 15: Robustness: the effect of curriculum implementation strategies on students' achievement; alternative measures of teaching practices

	Within pupils estimates		
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)
T1: Remaining on the same topic			
q2	0.0018	0.0016	0.0018
	(0.007)	(0.007)	(0.007)
q3	-0.0043	-0.0044	-0.0041
	(0.008)	(0.008)	(0.008)
q4	-0.0217**	-0.0217**	-0.0213**
	(0.009)	(0.009)	(0.009)
T2: Moving on to another topic			
q2	-0.0061	-0.0060	-0.0058
	(0.008)	(0.008)	(0.008)
q3	-0.0112	-0.0112	-0.0109
	(0.008)	(0.008)	(0.008)
q4	-0.0328***	-0.0326***	-0.0321***
	(0.010)	(0.010)	(0.010)
T3: Revising topics already studied			
q2	0.0055	0.0057	0.0056
	(0.007)	(0.007)	(0.007)
q3	0.0239***	0.0240***	0.0238***
	(0.008)	(0.008)	(0.008)
q4	0.0327***	0.0331***	0.0329***
	(0.010)	(0.010)	(0.010)
Observations	705,058	705,058	705,058

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies are the dummy versions (one for each quartile) of the three strategies T1-T3. For simplicity we omit the first quartile of each strategy. The three columns correspond to the specifications (3)-(5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 16: Robustness: the effect of curriculum implementation strategies on students' achievement; heterogenous effects

	Within pupils estimates		
6_{th} graders test score (standardized)	(1)	(2)	(3)
T1: Remaining on the same topic until everyone understands			
$\hat{\hat{\delta}}_{T1read}$	-0.0622**	-0.0671**	-0.0668**
	(0.026)	(0.026)	(0.026)
$\hat{\hat{\delta}}_{T1math}$	0.1495***	0.1478***	0.1459***
	(0.023)	(0.023)	(0.023)
T2: Moving on to another topic even if someone did not understand			
$\hat{\hat{\delta}}_{T2read}$	-0.2039***	-0.2170***	-0.2162***
	(0.030)	(0.030)	(0.030)
$\hat{\hat{\delta}}_{T2math}$	0.0930***	0.1072***	0.1055***
	(0.027)	(0.027)	(0.027)
T3: Revising topics already studied in the previous year			
$\hat{\hat{\delta}}_{T3read}$	0.2026***	0.2009***	0.2009***
	(0.032)	(0.032)	(0.032)
$\hat{\hat{\delta}}_{T3math}$	-0.0870***	-0.0817***	-0.0807***
	(0.026)	(0.026)	(0.026)
Observations	352,529	352,529	352,529

Notes: Estimates of the equation $\Delta y_{ick} = T'_{ijck_{read-i}}\delta_{read} - T'_{ijck_{math-i}}\delta_{math} + \Delta\tau_{ck} + \Delta\epsilon_{ick}$. These estimates include the same set of controls of the specifications in columns (3)-(5) of table 10. A positive coefficient for any of the strategies in math masks a negative relationship between the variables and the test scores performance in math, as the math parameters enter with a negative coefficient in the estimated equation. Viceversa, a negative coefficient in math has to be interpreted as a positive correlation between the variable and test scores performance in math. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 17: Robustness: the effect of curriculum implementation strategies on students' achievement; breakdown by pupils' ability - different ranking criteria

	Within pupils estimates		
	T1: Remaining on the same topic until everyone understands	T2: Moving on to another topic even if someone did not understand	T3: Revising topics already studied in the previoous year
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)
	Panel A: percentiles based on standardized school marks		
Effects for	-0.0348	-0.1320**	0.2826***
percentiles below 20	(0.048)	(0.057)	(0.065)
Effects for	-0.0828*	-0.1604***	0.1739***
percentiles 20-40	(0.048)	(0.058)	(0.067)
Effects for	-0.1047**	-0.1467**	0.1447**
percentiles 40-60	(0.049)	(0.060)	(0.066)
Effects for	-0.1628***	-0.1622***	0.1576**
percentiles 60-80	(0.047)	(0.060)	(0.062)
Effects for	-0.1599***	-0.1734***	0.0403
percentiles above 80	(0.044)	(0.055)	(0.062)
	Panel B: percentiles based on school mark ratio		
Effects for	-0.0536	-0.1339**	0.2697***
percentiles below 20	(0.047)	(0.058)	(0.067)
Effects for	-0.0426	-0.1620***	0.1709**
percentiles 20-40	(0.049)	(0.059)	(0.068)
Effects for	-0.1419**	-0.1382**	0.1600***
ercentiles 40-60	(0.049)	(0.060)	(0.068)
Effects for	-0.1403***	-0.1305**	0.1034
percentiles 60-80	(0.048)	(0.059)	(0.065)
Effects for	-0.1696***	-0.2216***	0.0640
percentiles above 80	(0.045)	(0.057)	(0.063)
	Panel C: percentiles based on test score performance (mean deviation)		
Effects for	-0.0732	-0.1240**	0.2906***
percentiles below 20	(0.045)	(0.056)	(0.064)
Effects for	-0.1336**	-0.1842***	0.2167***
percentiles 20-40	(0.052)	(0.064)	(0.072)
Effects for	-0.0936*	-0.1977***	0.1097
percentiles 40-60	(0.005)	(0.069)	(0.077)
Effects for	-0.1191**	-0.1533**	0.0281
percentiles 60-80	(0.054)	(0.065)	(0.076)
Effects for	-0.1643***	-0.1995***	0.0316
percentiles above 80	(0.0427)	(0.052)	(0.060)

Notes: The unit of observation is the student in a given subject. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. In Panel A the percentiles are defined ranking each student on the basis of the standardized mid term school marks. In Panel B the percentiles are defined ranking each student on the basis of the ratio between his/her across-subjects average of the mid term school marks and the class average. In Panel C the percentiles are defined ranking each student on the basis of the across-subjects average of test scores performance taken in mean deviation with respect to the class average. The specification includes the full set of controls of column (5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 18: Robustnes: the effect of curriculum implementation strategies on students' achievement; breakdown by pupils' ability - sample of homegeneous students across subjects

	Within pupils estimates		
	T1: Remaining on the same topic until everyone understands	T2: Moving on to another topic even if someone did not understand	T3: Revising topics already studied in the previoous year
Dependent variable: 6_{th} graders test score (standardized)	(1)	(2)	(3)
Effects for percentiles below 20	-0.0602 (0.070)	-0.1392* (0.084)	0.3330*** (0.098)
Effects for percentiles 20-40	-0.1149 (0.070)	-0.1770** (0.085)	0.2612*** (0.097)
Effects for percentiles 40-60	-0.0976 (0.074)	-0.1122 (0.089)	0.1193 (0.103)
Effects for percentiles 60-80	-0.1737** (0.068)	-0.0899 (0.084)	0.1347 (0.095)
Effects for percentiles above 80	-0.1677*** (0.065)	-0.2445*** (0.080)	0.0591 (0.089)

Notes: The unit of observation is the student. The dependent variable is the normalized percentage of correct answers (with mean zero and unitary standard deviation within subject). The teaching strategies variables are a class average of students' perceptions excluding the student's i own observation. The percentiles are defined ranking each student on the basis of his/her across-subjects average of the mid term school marks taken in mean deviation with respect to the class average. Estimates on a subsample of pupils with standard deviation between their own reading and math mid term school marks below the median. The specification includes the full set of controls of column (5) in table 10. Standard errors are clustered at class level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix

Table A–1: Unconditional distribution of students' perceptions

	Perceived T1: Remaining on the same topic until everyone understands	Perceived T2: Moving on to another topic even if someone did not understand	Perceived T3: Revising topics already studied in the previous year
1	66,371	438,327	52,485
2	265,733	177,043	202,010
3	298,404	65,537	336,472
4	74,550	24,151	114,091
Total	705,058	705,058	705,058

Notes: Unconditional distribution of students' answers for the perceived T1, T2 and T3 strategies. A value of 1 means a low perceived adoption of that practice, while 4 indicates that the student perceives an high frequency of adoption. Number of students. Pooled sample of subjects.

Table A–2: Conditional distribution of students' perceptions: T1-T2

Perceived T1/Perceived T2	1	2	3	4
1	35,244	13,434	9,734	7,959
2	162,968	70,467	27,048	5,250
3	187,618	81,634	22,787	6,365
4	52,497	11,508	5,968	4,577

Notes: Conditional distribution of students' answers for the perceived strategies T1 and T2. A value of 1 means a low perceived adoption of that practice, while 4 indicates that the student perceives an high frequency of adoption. Number of students. Pooled sample of subjects.

Table A–3: Conditional distribution of students' perceptions: T1-T3

Perceived T1/Perceived T3	1	2	3	4
1	13,102	21,734	21,542	9,993
2	21,658	89,408	128,532	26,135
3	13,695	80,291	153,963	50,455
4	4,030	10,577	32,435	27,508

Notes: Conditional distribution of students' answers for the perceived strategies T1 and T3. A value of 1 means a low perceived adoption of that practice, while 4 indicates that the student perceives an high frequency of adoption. Number of students. Pooled sample of subjects.

Table A–4: Conditional distribution of students' perceptions: T2-T3

Perceived T2/Perceived T3	1	2	3	4
1	29,371	126,523	207,007	75,426
2	11,393	48,341	95,025	22,284
3	7,003	21,984	26,416	10,134
4	4,718	5,162	8,024	6,247

Notes: Conditional distribution of students' answers for the perceived strategies T2 and the T3. A value of 1 means a low perceived adoption of that practice, while 4 indicates that the student perceives an high frequency of adoption. Number of students. Pooled sample of subjects.

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