NATIONAL RESEARCH UNIVERSITY
HIGHER SCHOOL OF ECONOMICS

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BASIC RESEARCH PROGRAM

WORKING PAPERS

SERIES: EDUCATION
WP BRP 06/EDU/2012

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The advantage of Trends in International Mathematics and Science Study is that not only does it perform a direct cognitive assessment of students concerning these students' teachers, but also their education, work experience and the instructional strategies used in their classes. In order to estimate teachers' characteristics effects on a student's achievements and overcome the limits of the TIMSS' correlational design, we have employed the first-difference method. Teachers' characteristics effects have also been measured with the usual regression method. The effects discovered varied from one subject field to another, and there has been a difference between the results gained by using the first-difference method and OLS regression analysis model. The first-difference method has revealed a negative effect of reproductive tasks and group work in math class, whereas comprehension tasks and tasks for developing meta-cognitive skills have shown a positive effect. On the contrary, reproductive tasks for science classes have had a positive effect while comprehension tasks and tasks for developing meta-cognitive skills have had either none or negative effects. Apart from this, a teacher's experience has had a significant effect on natural science subjects as opposed to mathematics. The possible interpretations of these results are discussed in this paper.

JEL Classification: I21, C21.

Key words: teacher's characteristics; student achievement; teaching practices; TIMSS; fixed effects regression; OLS regression; first difference estimators, quasi-experimental design.

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[3] The authors are grateful to Martin Carnoy for his help during our research

Introduction

Currently, teacher quality is treated as a crucial factor in the educational process and students' educational achievement (Fallon, 1999; Metzler & Woessmann, 2010). Broad reviews research on the effects of teachers' training (duration and specialization), pedagogical approaches towards teaching, teacher experience, and teachers' advanced professional training. The main components of "teacher quality" have been undertaken by Hanushek and Rivkin, 2006, Hedges, Laine, and Greenwald, 1994, Hanushek, Kain, and Rivkin, 2005, Clotfelter, Ladd, and Vigdor, 2006 and 2007. The general conclusion of such reviews is that the empirical results are mutually inconsistent and there is little agreement on any systematic teacher effects of specific teacher characteristics on student achievement.

It is obvious that the existing studies of teachers' characteristics effects involve different variables and methods that in many ways explain divergence in the results. How we answer the question, "Do teachers with a particular characteristic teach better than teachers with other characteristics?" depends not only on the actual influence that teacher characteristics exert on student achievement but also on the methodological features of a study itself. Apart from statistical analysis techniques employed which may result in their own specific biases, the answer to the question also depends on:

- how the quality "better educated student" was measured; what exactly was studied as an indicator of "being better/worse educated." The latter, for instance, could refer to poor progress at some stage of learning; passing/failing university admission examination; average grade; test scores and so on.
- what particular set of teacher characteristics was assessed and how these were measured. For example, this could be an amount of years spent by a teacher on his/her education; having/lacking an academic degree; a teacher's major; work experience etc. It is clear that those characteristics available for measurement were measured more often, but it is not evident that these are what really matters
- the design of data collection: on what sample of students, at what moment of time, with what frequency the data was gathered.

Apart from this, there also exists a whole number of methodological reasons for inconsistency between the results of teacher effect research. One of these reasons is that most of the studies in education are inherently correlational, i.e., non-experimental, (Schneider et al., 2007;

Seidel et al., 2007). According to the meta-analysis (Seidel et al., 2007), from 1997 through to 2007, studies of this sort made up two thirds of the general number. Approximately during the same period there emerged quite a few works that criticized the correlational approach to the study of this topic (Nye et al., 2004; Seidel et al., 2007). Correlational design potentially contains a multitude of limits for establishing causal relations between teacher characteristics and student achievements. Even if a researcher controls for certain variables, say, the socio-economic status of a student's family, it is difficult to ensure that no other latent variables remain that could have distorted the assessment results. For instance, students might be non-randomly distributed among teachers with various characteristics. We can assume that more capable students are more likely to study with teachers having better teaching skills. Teachers might be non-randomly distributed among schools; better qualified teachers often work at more prestigious and stronger schools. At the same time, those families with a higher socio-economic status (and, as a rule, with children making better academic progress) send their children to the same, more prestigious schools[4]. Students may be aligned by an entrance examination at schools in accordance with their academic performance. Finally, certain schools may implement some kind of a compensatory strategy of having more experienced teachers teach at classes with lower achievements. With usual regression analysis, these biases will inevitably result in either an over- or underestimation of teacher effects. Put differently, regression coefficients "represent a mixture of true 'teacher effects' and the 'sorting effect" (Pumsaran, 2010, pp. 34-35).

Of course some variables that can possibly bias results in regression analysis are usually taken under control. However, this still does not prevent other variables which have not been controlled from causing a bias. The spectrum of variables that can be taken under control will always be confined to measured variables and will never be exhaustive. Thus, regression models based upon cross-sectional data will always allow for the possibility of a bias. Its magnitude may be reduced, but their probability will never be entirely excluded.

One possible approach to solving this problem lies in using those methods of analysis which allow one to work with correlational research design as is quasi-experimental. Schneider et al. (2007) provide us with quite a comprehensive focus on such methods: the use of instrumental variables, estimation of propensity scores, fixed effects methods, and estimation of regression discontinuity. All these methods are aimed at reducing the effect of third, not measured variables that may become a reason for changes not taken into account. Choosing a particular method is

[4] Data for Russia - see, e.g., Andrushchak et al.(2011).

mainly determined by the features of data subjected to analysis. The most suitable option for TIMSS data, which would be the basis for the present study, is one of the fixed effects methods - the first difference method (FD), since TIMSS contains each particular student's test scores and the characteristics of those teachers with whom s/he studies these subjects. Therefore, by fixing the characteristics of the same student who is under the pedagogical influence of several teachers, we are thus minimizing the influence of unobserved variables, not measured student characteristics. After this fixing, all the differences that a student demonstrates in various subject fields of TIMSS can be attributed only to differences between his/her teachers. A logical conjecture about different student aptitudes to study various subjects, such as mathematics and biology, can and would be additionally investigated.

This study addresses two research questions:

1) Which teacher characteristics have a significant effect on eight-grade student achievements in TIMSS?
2) What are the consequences of applying two different methods - ordinary square regressions and first-difference method - for revealing significant teacher effects?

Later on in our study we are going to review the previous research relevant to our work. Then we will describe the methodology, and the results and discussion are in the two last sections.

Literature Review

We have already highlighted that the inconsistency in the results of assessing teacher effects might be associated with the diversity in research design and methods of studies. This means that in order to compare ours with other findings, it is necessary to take into consideration only relevant studies in terms of the following features:

- eighth-graders' performance (math and science) in TIMSS has become the dependent variable
- those teacher characteristics measured with the TIMSS questionnaire have become independent variables
- regression analysis has been used (ordinary or the first-difference method).

The review addresses the following questions: What are the teachers' characteristics effects on eighth-graders' achievements in TIMSS? What are the general characteristics of bias that emerge while assessing teachers' characteristics with the OLS method[5] and the FD method?

However, after narrowing down the range of studies with these criteria, the results are still not entirely comparable. Even when similar teacher variables were studied, they could be analyzed either as separate variables, indices, or as factors generated through factor analysis. Thus, it is difficult to ensure that the researchers deal with the same variables in all cases. Nevertheless, below we provide a somewhat generalized picture of just what effects teacher and school characteristics have on eighth-graders' achievements, what kind of effects exactly, and under what conditions.

K. Yee (2007) has demonstrated that developing mathematical meta-skills in class (for example, solving tasks that do not have an unambiguous or unique solution), using computers in math lessons, and using textbooks as a basis for classes positively affect eighth-graders' achievements in TIMSS. R. Zuzovsky (2007) has not revealed any systematic effects either for different subject fields or for students with high and low aspirations for education. The authors' findings suggest that a teacher's gender (female) has a positive relationship to student achievements for those students with an aspiration for higher education.

From all the teacher education characteristics, the following have proven positively significant:

- the highest educational level attained (positive relationships with achievements in science, negative for math);
- relevant area of teacher's major (negative relationships for math teachers;
- positive for science teachers);
- degree of involvement in professional development with focus on content (positive relationships only for math and only those students with low aspirations for educational attainment desired);
- extent of involvement in professional development with focus on pedagogy (negative relationships for students with low aspirations for educational attainment desired).

S. Pong and A. Pallas (2001) have found out that class size is nonlinearly connected to achievements in all the countries they studied. It turned out that those students who attended larger

[5] Ordinary Least Square. In our text we will specifically stipulate the cases where quasi-experiments were conducted, all the other cases would simply imply the use of the ordinary least square method (OLS).

classes in countries with a centralized education system outstrip their peers from smaller classes in terms of achievements. In contrast to this, in countries with a decentralized education system, negative relations have been revealed between class size and math achievements.

There are few studies where the same data was analyzed with two methods (ordinary regressions and the first-difference method).

In Pumsaran's work (2010) which analyzed the TIMSS results from 1999 through 2007 with two models (OLS и FD), the following independent variables have become key; teacher's gender and experience, availability of certificate, teacher's educational level (BA or MA) and his/her major during the process of study. The FD model has shown different results as compared to the OLS model in regard to almost all the variables, except a teacher's experience and the absence of a BA degree which had significantly positive effects in both models. Overall, the amount of the discovered significant effects decreased when the FD models were applied and they became more consistent across the waves of study and the subjects. Apart from the mentioned effects of a teacher's experience and the educational level attainted, the author has also found out that a teacher's MA degree is positively connected with a student's achievements, and female teachers have students with higher scores in TIMSS than male teachers.

Klaveren (2011), besides the variables discussed above, also delves into the various effects of teaching styles, paying specific attention to "lecturing style" when a teacher lectures to a whole class. Switching from the OLS model to the FD model, no significant effects of lecturing style teaching on student achievements were detected (although in the OLS model showed such effects on a significant level both for math and for physics). The results of checking other teacher characteristics were not in concordance with Pumsaran's (2010) results; a teacher's degree has demonstrated an effect for achievements while experience has not.

Falch and Rønning (2011) have shown that FD gives results different from OLS in assessing the effects of home tasks on TIMSS results. In particular, they have discovered a significant positive connection between the amount of homework and TIMSS scores if we assess this relationship with FD. The OLS model has not shown such an effect.

Unfortunately, each of the studies mentioned above contained its own set of variables which means there was practically no reassessment of the same variables. It is thus impossible to assert anything about how stable the effects discovered are for various countries and waves of studies.

Only Pumsaran (2010) has revealed a consistency in teachers' education effects between the two waves of TIMSS, with the exception of a BA and MA degree; their effects varied from year to year.

Of course, some variables are more likely to show an effect varying from one study to another even in quasi-experimental models of analysis. This will be the case when a studied characteristic directly depends on a national system of education, its changes and national standards. For example, teachers' professional training, their advanced professional training and competency requirements behind BA and MA degrees may vary from country to country and thus produce different effects. A teacher's gender may apparently show various effects, primarily due to a different proportion of female teachers in different countries. Therefore, some parameters may matter only on a national level and naturally differ in international comparisons.

Some data of Russian research (Основные результаты…, 2008) allow us to maintain that the most part of the dispersion in student achievements in TIMSS is associated not with school or classroom characteristics, but with the socio-economic status of a student's family. However, there is no data on which school and teacher factors are significant for Russian students' achievements. This paper is the first systematic attempt in Russia to evaluate the effects of a Russian teacher's quality on student achievements in TIMSS.

System of education, curriculum and teacher education in the Russian Federation

General education (grades 1–9) is compulsory according to the Constitution of the Russian Federation. It consists of primary and secondary education, which includes lower secondary and upper secondary education.

The compulsory minimum content for basic school mathematics education includes the following four sections:

• *Arithmetic*: natural numbers, fractions, rational numbers, real numbers, word problems, measurements, approximations and estimations.

• *Algebra*: algebraic expressions, properties of powers, equations, inequalities, solving word problems algebraically, number sequences, functions and coordinates.

• *Geometry*: basic geometry concepts and theorems, angles, lines, circumference and circles, intuitive ideas of spatial bodies, triangles, trigonometry, quadrangles, polygons, geometric measurements, areas of plane figures, volumes of solids, vectors, geometric transformations and geometric construction using a ruler and a compass.

• *Elements of logic, combinatorics, and statistics and probability*: proofs, sets and combinatorics, and statistical data and probability.

Regarding science education, it should be noted that in the Russian educational system there are no single and integrated subjects like "science". Science as an integrated subject is taught only in 5th grade. After that, the Russian schoolchildren study several subjects: biology and geography (starting from 6th grade), physics (from 7th grade) and chemistry (from 8th grade). The compulsory minimum content for basic school science education is summarized below for all science subjects by the main topics studied:

• *Biology*: biology as part of the natural sciences; biological methods; characteristics of living organisms; the system, diversity and evolution of living nature; human biology and health and the interaction of organisms and the environment.

• *Geography*: sources of geographical information (geography as part of the natural sciences and geographic models); the nature of the Earth and humans (Earth as a planet); the Earth's crust and lithosphere; the hydrosphere, atmosphere, biosphere, and soil (the geographic shell of the Earth); continents and oceans; nature management and geo-ecology and the geography of Russia.

• *Physics*: physics and physical methods of nature study, mechanical phenomena, thermal phenomena, electromagnetic phenomena and quantum phenomena.

• *Chemistry*: methods of studying substances and chemical phenomena, substances, chemical reactions, the elementary basis of inorganic chemistry, primary ideas about organic substances, the experimental basis of chemistry, and chemistry and life.

Traditionally, homework is assigned for each lesson in primary and secondary school for all subjects. In practice, in 4^{th} grade, teachers assign mathematics and science homework for 15–30 minutes and in 8^{th} grade, for 30 minutes.

There are several different ways to become a secondary education teacher. Teacher education may include 5 years of formal education at a pedagogical institution with qualifications as a teacher of mathematics, physics, chemistry, biology, or a combination of these; 4 years of higher education, with a Bachelor of Physics/Mathematics (or Science) Education; or 6 years of higher education with the qualification of Master of Physics/Mathematics (or Science) Education. It should be noted that two latter ways to achieve a teacher's education are not widespread for now, and the vast majority of Russian teachers have 5 years of formal education.

Another way to become a secondary school teacher is to be educated as a mathematician (biologist, physicist, chemist or geographer) in university. Although the period of time for education is the same in a pedagogical institute and in university, the latter gives more academic and wider education and doesn't focus upon pedagogic knowledge and skills.

Professional development is no longer compulsory and depends on possibilities and attitudes of teachers, school principals, and regional departments of education and so on.

Russian achievements in TIMSS

During all the years of participation in TIMSS, Russian students have not demonstrated any notable changes. Their success in math and science can rather be described by descending curves (Figure 1). Even if we take a significant increase in scores between 2003 and 2007 into account, the latest achievements of Russian eight-graders still do not exceed those of their peers in 1995.

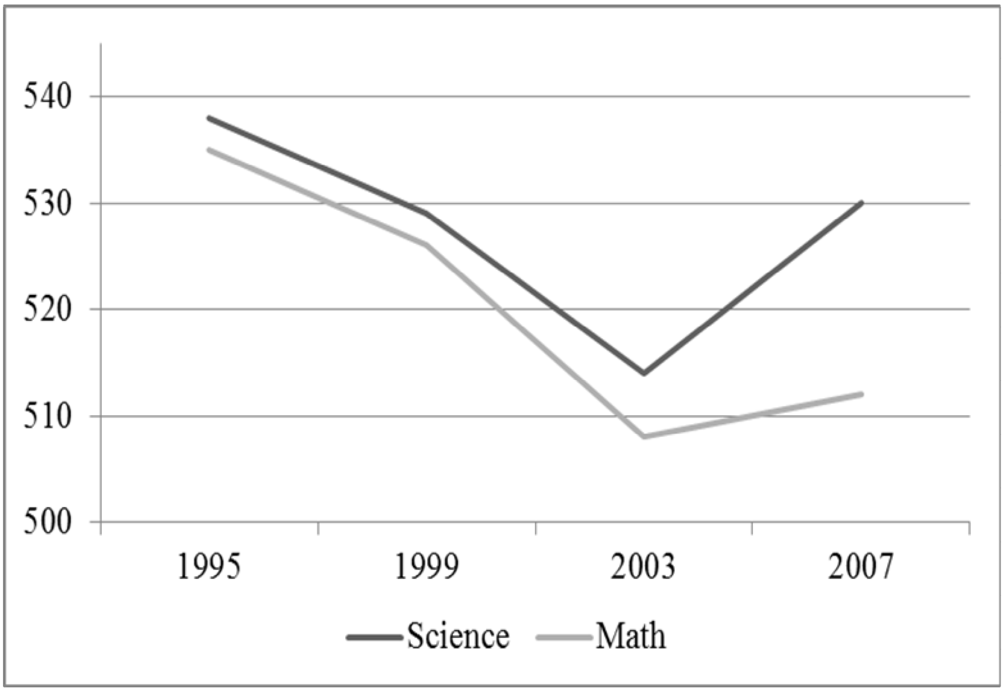

Figure 1. **Trend in Russian eighth-graders' achievements in TIMSS (1995-2007).**

Methodology

Sample

The Russian TIMSS 2007 sample consists of 4472 8^{th} grade students from 210 schools in 58 regions. The sample is representative of schools. In each school one of 8 grades is interviewed.

In order to assess a teacher's effects, in our paper, along with ordinary regressions (OLS) we have also employed first-difference estimators (FD) Dee, 2008; Brüderl, 2005). First-difference estimators for regressions with fixed effects are commonplace in panel studies where characteristics pertaining to the same respondent are compared for two periods of time. In our case, instead of applying first-difference estimators to two periods of time, we used them in order to instantly assess two characteristics of the same students (for instance, achievements in math and physics).

With two series of data, we can obtain the following regression equations:

The first observation (e.g., math): $y_{i\text{м}} = \beta_1 x_{i\text{м}} + \beta_2 z_i + v_i + \varepsilon_{i\text{м}}$

The second observation (e.g., physics): $y_{i\text{ф}} = \beta_1 x_{i\text{ф}} + \beta_2 z_i + v_i + \varepsilon_{i2}$

where x_i is the teachers' characteristics vector, z_i is the student characteristics vector and v_i is the person-specific unobserved heterogeneity. This is a person-specific time-constant unobserved heterogeneity; ε_i is a random error. The equation does not contain a constant since the latter correlates with v_i.

By subtracting the first equation from the second, we can eliminate person-specific student characteristics from the model:

$\Delta y_i = \beta_1 \Delta x_i + \Delta\varepsilon_i,$

where Δ means the difference between the values in two observations.

Regression coefficients are further obtained via the OLS regression (Brüderl, 2005, p.6).

We thus get rid of a shortcoming that the correlational design has; the impossibility of taking into account all student characteristics, which might be associated both with their own achievements and with the characteristics of their teachers.

The main idea of our research that underpins this method is that we treat each student as an observation which is exposed to experimental impact - he/she studies under the guidance of two teachers with different characteristics, whereas all other student features remain fixed. We control for all the person-specific characteristics except one, different teachers, and here lies the main advantage of this approach. We rule out all possible alternative explanations of variance in student achievements at various subjects, as all latent student characteristics are now fully leveled. The only aspect in which the situations are dissimilar is in the different teachers that the same student has; in one case it is a math teacher, in other, a science teacher. Now, however, the dependent variable is not simply a student's score in the TIMSS test but the difference between two tests and, therefore, interpreting the results becomes harder than it was when using ordinary regression. However, the advantage of creating a quasi-experimental design based on cross-sectional data significantly overrides this drawback and considerably widens the possibilities of working with data provided by international comparative studies.

Cluster correction

The TIMSS data have a hierarchical three-level structure: class level (all students in class are surveyed), teacher level and school level. The fact that students are gathered in one class can produce its own biases, and class level observations cannot be considered independent from each other. As a rule, this leads to an underestimation of regression coefficients' standard errors. The cluster correction procedure which we employ allows us to take this fact into account and to correctly estimate the errors.

Description of the Model

As shown in reviews of similar studies, the most frequently analyzed teacher characteristics when TIMSS data is used are educational characteristics (a teacher's credentials, educational level, having a pedagogical education and education exactly in the area of a subject he/she teaches), experience, teacher practicing for lessons and preparing for them, a teacher's self-evaluation of readiness to teach a given subject, a teacher's attitudes and expectations, socio-demographic characteristics, and the ratio of a given subject's different substantive parts in the curriculum.

In the first stage, we created a minimal set of characteristics to be included into model №1: education, experience, and gender. It was especially important to us to study the relationship between a teacher's education and the student's achievements, because the teacher's education is currently being widely discussed amongst the Russian professional community.

However, not all TIMSS questions can be considered relevant for the Russian context. For instance, regarding the educational level, more than 98% of teachers (according to TIMSS 2007 data) have a higher level of education. When teachers acquired their higher education, there was no division between the MA and the BA in Russia. More than 98% of math teachers are educated in the sphere of math, the picture with sciences is similar. In other words, the education-related and major-related variables have equal values for all teachers and, therefore, it is senseless to treat them as predictors of any differences. From our standpoint (and TIMSS data allow us to conclude as such), in Russian pedagogical education it is compelling to examine the scope of a teacher's education, for example, whether or not a math teacher has some other major except a major in math. Thus the question, "What are the main areas of your professional education?" was crucial to us.

However, beforehand we had to restructure the data so each teacher would belong to a single category, not to several at once as in the initial database. For this purpose, based on the original question we have formulated the following answer categories:

Math teachers:

1. Only math /[6] Math AND math teaching methods
2. Math AND math teaching methods AND general pedagogy / Math AND math teaching methods AND general pedagogy AND sciences AND/OR sciences teaching methods
3. All other options

Physics teachers:

1. Only physics / Physics AND sciences teaching methods / Physics AND any other major AND no sciences teaching methods AND no general pedagogy
2. Physics AND science teaching methods AND general pedagogy / Physics AND sciences teaching methods AND general pedagogy AND/OR any other major
3. All other options

Biology teachers:

1. Only biology / Biology AND sciences teaching methods / Biology AND any other major AND no sciences teaching methods AND no general pedagogy
2. Biology AND sciences teaching methods AND general pedagogy / Biology AND sciences teaching methods AND general pedagogy AND/OR any other major
3. All other options

Chemistry teachers:

[6] The "/" sign separates one type of teacher's education from another. Aggregative categories comprised two or three types of education.

1. Only chemistry / Chemistry AND any other major AND no sciences teaching methods AND no general pedagogy
2. Chemistry AND sciences teaching methods AND general pedagogy / Chemistry AND sciences teaching methods AND general pedagogy AND/OR any other major
3. All other options

When we separated the categories in this way, we tried to draw a distinction between education acquired at a teachers' training institution from a university education. Since there is no direct question in TIMSS about this distinction, in our view, we can use teacher education in general pedagogy as an indicator for a teachers' training institution. This is why the first category included the teachers having an education in the same area that they teach, probably with a teaching method for this discipline, but without general pedagogy. The second category included the teachers who studied their core subject and had an education in general pedagogy.

The *Teacher's experience* variable was comprised of the following intervals: less than 3 years; 3 to 10 years; 11 to 20 years; More than 20 years.

In the model №2 we added the characteristics of pedagogical approaches towards teaching as independent variables (teacher practices).

The questions that have been included are:

1. "How many minutes per week do you teach … to the TIMSS class?"

2. Questions about a teacher's emphasis on homework. TIMSS indexes this by putting the answers into three categories: high, medium, low.

3. Distribution of class time (in percents) on various activities. "In a typical week of lessons for the TIMSS class, what percentage of time do students spend on each of the following activities? (*Write in percent. The total should add to 100%.*).

The response options were grouped in four categories reflecting different kinds of teacher's practices:

<u>Frontal</u>: *Reviewing homework; Listening to lecture-style presentations; Working on problems with your guidance; Listening to you re-teach and clarify content/procedures.*

<u>Individual work: *Students*</u> *work on problems without your guidance.*

<u>Control</u>: *Students take tests or quizzes.*

<u>Wasting of time</u>: *Teacher deals with tasks not related to the lesson's content/purpose (e.g., interruptions and keeping order).*

If a category contained more than one question, we included the average for all the answers into our analysis. Thus, a higher value and prevalence of a given teacher's practice went hand in hand.

4. The distribution of various types of student cognitive activities in class. The question: "In teaching the students in the TIMSS class, how often do you usually ask them to do the following? (Every or almost every lesson; About half of the lessons; Some lessons; Never)" was also structured for four types of activities.

For math lessons:

Repetitive: *Practice adding, subtracting, multiplying, and dividing without using a calculator; Work on fractions and decimals; Apply facts, concepts and procedures to solve routine problems; Memorize formulas and procedures.*

Understanding and interpretation: *Use knowledge of the properties of shapes, lines and angles to solve problems; Explain their answers; Interpret data in tables, charts or graphs; Write equations and functions to represent relationships*.

Meta skills: *Relate what they are learning in mathematics to their daily lives; Decide on their own procedures for solving complex problems; Work on problems for which there is no immediately obvious method of solution.*

Group work: *Work together in small groups*.

For science lessons:

Repetitive: *Watch me demonstrate an experiment or investigation; Have students memorize facts and principles; Give explanations about something they are studying; Use scientific formulae and laws to solve routine problems; Read their textbooks or other resource materials.*

Understanding and interpretation: *Observe natural phenomena and describe what they see; Conduct experiments or investigations.*

Meta skills: *Design or plan experiments or investigations; Relate what they are learning in science to their daily lives.*

Group work: *Work together in small groups on experiments or investigations.*

If a category included more than one answer, then we calculated the sum of points received for each block of variables, and normalized the result by dividing by the maximum. Then, the result was subtracted from one so that the higher scores correspond to a higher level of prevalence of the activity. The minimum value is 0 and the maximum is 0.75.

The overall model (model №3) was comprised of a teacher's characteristics (education, experience, gender), their practices (duration of teaching the subject; amount of home tasks; pedagogic in-class practices), and the time spent on certain topics. In order to take statistically significant differences between boys' and girls' achievements into account, an aggregate variable reflecting the percentage of girls in a class was included into the overall model.

As a result, three models have been assessed.

The difference between student achievements in TIMSS in various subjects (standardized scale) served as a dependent variable. Three additional variables have been calculated for each student: 1) (math score) - (physics score); 2) (math score) - (chemistry score); 3) (math score) - (biology score). Regression models were subsequently created for each of these variables. The final regression equations (for example, comparing between math teachers (M) and physics teachers (P)impacts):

For the model №1:

Score in math – score in physics = constant + ***B1****educationM +* ***B2****educationPh +* ***B3****experinceM +* ***B4****experiencePh +* ***B5****genderM +* ***B6****genderPh + ε* (1)

For the model №2:

Score in math – score in physics = constant + ***B1****teaching_practicesM +* ***B2****teaching_practicesPh + ε* (2)

For the full model №3:

Score in math – score in physics = constant + ***B1****educationM +* ***B2****educationPh +* ***B3****experinceM +* ***B4****experiencePh +* ***B5****genderM +* ***B6****genderPh +* ***B****7tteaching_practicesM +* ***B8****teaching_practicesPh +* ***B9(****M=P) + ε* (3)

Apart from the first-difference regression analysis, we have created the OLS models. The TIMSS score for one of the 4 subjects has been used as a dependent variable (also standardized). The above described characteristics have been used as independent variables.

Results

Descriptive Statistics

Among science disciplines, the Russian students are the least successful in physics and most successful in chemistry. Only in physics have significant gender differences been revealed; boys demonstrate higher results than girls (Figure 2).

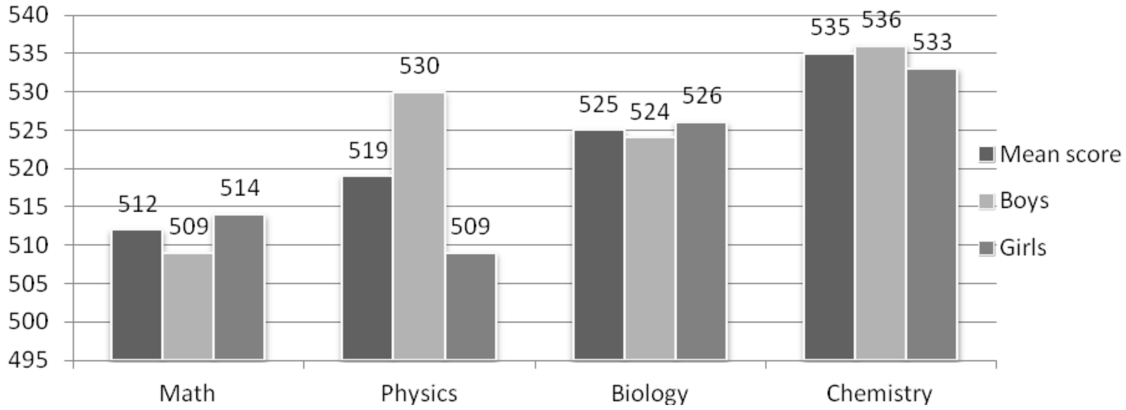

Figure 2. Russian eighth-graders' achievements in TIMSS 2007.

Russian teachers' answers concerning their major show that almost a half of those who teach a certain major have not had this major as their general pedagogy (Table 3).

Table 1. Russian teachers' major (based on TIMSS 2007 data).

Major	Percent
***Math teachers*:** 1. Math only / Math AND Math educ	37,8
2. The same AND General pedagogy	44,7
3. All other variants	17,5
Physics teacher: 1. Physics only/Physics AND Science education/Physics AND no General pedagogy AND else	45,5
2. The same AND General pedagogy	39,7
3. All other variants	10,1
Biology teachers: 1. Biology only/Biology AND Science education/Biology AND no General pedagogy AND else	39,4
2. The same AND General pedagogy	46,3
3. All other variants	14,3
Chemistry teachers: 1. Chemistry only / Chemistry AND Chemistry only / Chemistry +	47,4

Major	Percent
no General pedagogy AND else	
2. The same AND General pedagogy	44,4
3. All other variants	8,2

As for teacher practices, more than half of math teachers reported that their students practically at every lesson are engaged in the following kinds of activity: practicing adding, subtracting, multiplying, and dividing without using a calculator, applying facts, concepts and procedures to solve routine problems and explaining their answers (total index of a reproductive kind of activity - 0,79) (Table 4). The students tend to be engaged in interpreting data in tables, charts or graphs and deciding on their own procedures for solving complex problems ("meta-skills" index - 0,38) and working together in small groups much less frequently. In these questions, the mode and the median fall on the "At some lessons" response.

Table 2. Prevalence of different kinds of assignments during lessons (based on TIMSS 2007 data).

Kinds of assignment	Math	Physics	Biology	Chemistry
Repetitive	0,79 (0,17)	0,67 (0,18)	0,65 (0,16)	0,67 (0,18)
Understanding and interpretation	0,65 (0,13)	0,58 (0,11)	0,41 (0,15)	0,52 (0,14)
Meta-skills	0,38 (0,16)	0,57 (0,17)	0,61 (0,14)	0,57 (0,17)
Group work	0,46 (0,21)	0,39 (0,18)	0,39 (0,18)	0,41 (0,19)

Note: Mean and Standard errors (in parentheses) are shown.

Regarding the chemistry teachers' answers, we can conclude that students most frequently use scientific formulae and laws to solve problems and give explanations about something they are studying (more than half of the teachers use this teaching method in each class). In approximately half of the lessons, students watch their teacher conduct an experiment, and memorize definitions, rules, facts and laws. Less frequently, they plan an experiment and observe natural phenomena. In most biology lessons, students give explanations about something they are studying, and in almost half of these cases they memorize rules, facts, and laws and read their textbooks. The most frequent practices in physics classes are explanations given by students about something they are studying and using scientific formulae and laws to solve problems.

It can be said, in general, that in more than half of the classes in every subject, reproductive learning occurs. However, science teachers much more frequently practice «meta-skills» assignments in teaching, primarily when it comes to how things that they study are connected to real life and conducting experiments.

Concerning forms of interactions between a class and a teacher (Table 5), one can see that in all subjects teachers spend approximately a similar percentage of time on similar kinds of work. This lack of a significant difference is probably a sign of a centralized curriculum prescribing what and how often a teacher should take a class. It can be observed that the most frequent kind of activity is the students' individual work and tests. Then the teachers' frontal work with a class follows and a short amount of time teachers dedicate to aspects not related to the lesson's content (for example, discipline issues).

Table 3. **Distribution of class time (in percents) on various activities (based on TIMSS 2077 data).**

Teachers:	Math	Physics	Biology	Chemistry
Frontal teaching	11,87 (2,7)	12,12 (3,31)	12,61 (3,38)	12,95 (3,26)
Individual work	19,75 (7,85)	16,35 (7,23)	15,96 (8,03)	14,92 (7,1)
Control	16,39 (6,35)	15,69 (6,98)	14,25 (7,06)	14,89 (7,88)
Wasting of time	1,23 (2,16)	1,57 (2,63)	1,51 (2,4)	1,18 (2,15)

Note: Mean and Standard errors (in parentheses) are shown.

Descriptive statistics for homework have shown that the amount of assignments that Russian teachers give is either medium or high. The "minutes per week spent on teaching the subject" variable has a rather small standard deviation for all the subjects, which means that the amount of hours spent on teaching is determined by educational standards and is much the same in all schools.

As we have mentioned earlier, using fixed effects methods, we assumed all student characteristics, including aptitudes for various subjects, to be constant. In order to check this assumption, we have calculated the Pearson correlation coefficients for student scores in math and other subjects. The results have shown that in all cases the correlation approximately equals 0,8 ($p<0,001$). This enables us to conclude that those students apt at studying math are almost equally apt at studying sciences. In other words, this justifies the relevance of applying regressions with fixed effects.

Regression models results

Ordinary Least Square Method (OLS)

Appendix Table 1 demonstrates the results of running the OLS regression analysis. As we can see, this method revealed many statistically significant relations between a teacher's characteristics and a student's achievement. Among formal teacher characteristics, only having general pedagogy as a major has shown an effect (positive), but this is exclusively for physics. The number of minutes per week spent on teaching the subject (positive effect) and the amount of homework assignments (negative effect) also were important only for physics. Repetitive activities in lessons have shown a negative effect for biology and chemistry, but only in the full model. Understanding and interpretation assignments during lessons have shown a positive effect for physics and chemistry. Developing meta-skills in students has positively affected the results in all areas, except physics. Group work and frontal learning have shown a negative effect, but only for math. The percentage of time that a teacher spends working on the "Data" topic revealed a small positive effect. By and large, despite some exceptions, the OLS has discovered quite consistent results in all the models.

We do not provide a wider interpretation here, since the initial reliability of these findings should be checked with quasi-experimental models.

First difference estimates (FD).

In the FD approach on the analysis of a teacher's effect on math achievement, we deal with three comparisons: math – physics, math – biology, and math – chemistry. It is reasonable to assume that if a math teacher's characteristics have an effect on all three juxtapositions, then we can assert that this characteristic of math teachers causes the revealed effects in a highly stable manner. Such a stable, though negative, effect in all three comparisons has been shown by group work at math lessons. No other recurring effects have been detected (Appendix, Table 2).

Apart from this, teachers with 3-20 years of experience have students with higher scores in math. Another positive effect has been demonstrated by the tasks that we designated as meta-skills. A small, though significant, positive effect has been shown by the amount of time a teacher spends on working with the "Data" topic.

Although the effects discovered in other domains - physics, biology, and chemistry - are quite consistent, often they are surprising (Appendix, Table 2). For example, repetitive activities in lessons have shown themselves to be important in physics, and furthermore have shown a positive effect. At the same time, the practice of understanding and interpretation tasks has demonstrated a negative effect on achievements in physics.

In the biology domain, a teacher's wider experience, including that of over 20 years, is linked with better student achievements. Larger amounts of homework assignments are linked with higher achievements. At the same time, the "meta-skills" task group has had a negative effect. These effects are stable in all three models.

Finally, repetitive activities have shown a positive relationship to results in chemistry. Interpretation tasks have had a negative effect. These effects have appeared in all the models.

Discussion

First of all, in various subject areas various teacher characteristics have proven significant. The effects revealed with the first-difference method quite clearly differ between the mathematical and scientific domains. In science, for example, it is rather a teacher's wide experience and repetitive tasks (reading textbooks, memorizing facts and laws, watching a teacher demonstrate an experiment or investigation and solving routine problems) that are of primary importance. At the same time, interpretation or meta-skills tasks (observing and describing natural phenomena and conducting experiments) rather bring down achievements in a subject.

Quite the opposite is true for math; the more experienced (more than 20 years) the teacher is and assignments of a reproductive type in lessons relate to a lower achievement, while interpretation or meta-skills tasks have positive effects. As strange as this inconsistency might seem, it should be kept in mind what has been included into this task’s category in math and what has been included in science. For example, in sciences, interpretation or meta-skills included observing natural phenomena and describing what was seen and conducting experiments. Tasks like this do not really increase one’s knowledge and skills just by being assigned. What is needed here is a teacher's own ability to control the process of empirical research, which a student conducts. The teacher should guide students in making correct inferences or asking follow-up questions. If we continue this train of thought, we can assume that this process also requires that a teacher has his/her own research reasoning. It is obvious that when most Russian teachers were receiving their education, it was not on the agenda to build up such a competency in teachers. The present standard calls for understanding, interpretation and meta-skills tasks. Judging by the answers of the teachers who participated in TIMSS, they meet the standard requirements, although it seems that they are not able to control the process of learning so as to make these kind of activities lead to positive outcomes.

The situation was different for math. Here, the understanding and meta-skills task category included activities not analogous to those in science. For example, the math area does not contain such tasks as conducting experiments or observation, description of results, and their interpretation. Understanding and meta-skills tasks in the math area were comprised of interpreting charts, writing functions to represent relationships, solving complex problems and so forth.

Perhaps solving non-routine problems in math lessons improves a student’s skills by itself. In other words, integrating such tasks into a teacher’s practice in math has a positive effect simply by being a part of a syllabus. In science, using tasks of this type in lessons requires special teacher competence, otherwise these tasks "don't work."

In math, group work is the only kind of activity measured in TIMSS where the role of a teacher's managerial, diagnostic, and prognostic abilities is obvious. And here again, as in the case of "experimenting" in science, the negative relation between this kind of teacher practice and student achievements is revealed. By no means can students benefit from this format of teaching (e.g., group work) itself, even if it is considered necessary by educational standards. Of course, tasks might have some rich potential. In some cases, these very tasks themselves (e.g., interpreting charts or solving non-routine problems in math) suffice to increase a student’s achievements. In other cases, additional input (group work guidance, experimenting) from a teacher is needed for a task’s ' potential to be fulfilled. And if a teacher cannot live up to this job, an assignment takes up class time and thereby causes a decline in results.

As has been frequently emphasized, , the FD method should correct biases the distribution of students between teachers and schools (Pumsaran, 2010; Klaveren, 2011; Falch and Rønning, 2011). One should take this into account while interpreting the differences between results yielded by the traditional OLS analysis and the FD method. The similarities between results in FD and OLS means that a given attribute has not been significantly biased, whereas the difference means that this teacher’s characteristic is distributed non-randomly between students and schools.

In the math domain, the transition from OLS to FD removes the negative effect of frontal learning and introduces a positive effect on? teacher experience. This implies that more and less experienced teachers are assigned to schools in a non-random way, whereas students are non-randomly assigned to teachers who spend a lot of time on frontal work with a class. Judging by the fact that frontal learning's positive effect disappears in the FD model, we can assume that better prepared students more frequently learn with those teachers who spend a significant amount of time on frontal work with a class.

Other results in math have not undergone changes while switching to the FD model, so it can be asserted that students are distributed more or less randomly between teachers who use understanding, interpretation, and meta-skills tasks in their work.

In science disciplines, when switching from OLS to FD, certain teacher practices such as understanding and meta-skills tasks and group tasks lose their positive effect. Obviously, teachers simply use these pedagogical approaches with students who are initially better prepared, but these practices by no means lead to them being better prepared.

At the same time, with transition to the FD models, reproductive tasks show positive effects which were not seen in the OLS analysis. Apart from this, a positive effect of a teacher's wide experience is revealed (biology). In terms of a students' distribution between teachers, this means that better prepared students are more likely to study science disciplines with teachers who have medium or small experience.

On the whole, the analysis has shown that all significant teacher characteristics in science disciplines are subject to bias, since for all of them the transition to the FD model reveals a change of effect. Thus, not only has the application of a new methodological approach allowed us to answer the research question on the connection between a teacher's characteristics and a student's achievements, it has also helped us to reveal certain characteristics that are practiced by all teachers, and characteristics pertaining only to some of them; for example, those teachers who work at schools with a certain socio-economic status or with better prepared students. This information is valuable in itself and it might well be useful for planning future research, especially into experimental design.

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Appendix

Table 1. OLS models

	Mathematics			Physics			Biology			Chemistry		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Education2	0,11	0,05		0,20**	0,17**		0,08	0,05		0,02	-0,05	
	(0,10)	(0,09)		(0,09)	(0,08)		(0,09)	(0,09)		(0,08)	(0,09)	
Education 3	0,09	0,03		0,07	0,14		-0,14	-0,11		-0,00	-0,08	
	(0,12)	(0,12)		(0,13)	(0,13)		(0,13)	(0,15)		(0,15)	(0,13)	
Experience_3-10	0,34	0,30		-0,14	-0,08		0,04	0,07		0,43	0,44	
	(0,28)	(0,31)		(0,22)	(0,19)		(0,28)	(0,27)		(0,39)	(0,32)	
Experience_11-20	0,22	0,07		-0,03	-0,12		0,23	0,17		0,35	0,30	
	(0,27)	(0,31)		(0,20)	(0,18)		(0,28)	(0,27)		(0,38)	(0,31)	
Experience_21+	0,19	-0,00		-0,02	-0,04		0,23	0,18		0,43	0,32	
	(0,26)	(0,31)		(0,20)	(0,17)		(0,27)	(0,27)		(0,38)	(0,32)	
Sex (teacher, 1=female)	0,05	-0,06		0,14	0,00		0,02	0,01		-0,01	0,05	
	(0,21)	(0,22)		(0,12)	(0,10)		(0,04)	(0,04)		(0,26)	(0,26)	
Minutes teaching		0,00	0,00		0,01**	0,00*		0,00	0,00		-0,00	-0,00
		(0,00)	(0,00)		(0,00)	(0,00)		(0,00)	(0,00)		(0,00)	(0,00)
Homework (high)		0,05	0,06		-0,20**	-0,24***		0,08	0,07		0,06	0,05
		(0,08)	(0,08)		(0,09)	(0,09)		(0,13)	(0,13)		(0,10)	(0,09)
TP[7]_ repetitive		-0,20	-0,16		0,02	-0,03		-0,55**	-0,58**		-0,48*	-0,49**
		(0,31)	(0,31)		(0,21)	(0,21)		(0,25)	(0,25)		(0,25)	(0,25)
TP_understanding and interpretation		0,45	0,41		1,60****	1,46****		0,18	0,08		0,98***	1,07***
		(0,34)	(0,34)		(0,40)	(0,39)		(0,36)	(0,35)		(0,34)	(0,34)
TP_meta skills		0,93***	0,92***		-0,40	-0,29		0,82**	0,83***		0,58**	0,47*
		(0,33)	(0,33)		(0,25)	(0,24)		(0,33)	(0,31)		(0,24)	(0,24)
TP_group work		-0,49*	-0,46*		0,33	0,45*		0,27	0,24		-0,00	0,03

[7] TP - Teaching Practice.

		(0,26)	(0,25)		(0,24)	(0,25)		(0,24)	(0,23)		(0,25)	(0,25)
TP_frontal (%)		-0,08** (0,03)	-0,07** (0,03)		-0,01 (0,03)	-0,00 (0,03)		-0,06 (0,05)	-0,05 (0,05)		0,01 (0,04)	0,01 (0,04)
TP_individual work (%)		0,00 (0,01)	0,00 (0,01)		0,01 (0,01)	0,02* (0,01)		-0,00 (0,01)	0,00 (0,01)		0,01 (0,01)	0,01 (0,01)
TP_control (%)		-0,01 (0,01)	-0,01 (0,01)		-0,00 (0,01)	0,00 (0,01)		-0,01 (0,01)	-0,00 (0,01)		0,01 (0,01)	0,01 (0,01)
TP_senseless spending of time (%)		-0,03 (0,02)	-0,02 (0,02)		-0,02 (0,02)	-0,02 (0,02)		-0,02 (0,02)	0,00 (0,02)		0,00 (0,02)	0,01 (0,02)
Sex (student, 1=female)	0,06 (0,04)	0,06 (0,04)	0,06 (0,04)	-0,26**** (0,04)	-0,25**** (0,04)	-0,25**** (0,04)	0,03 (0,04)	0,01 (0,04)	0,00 (0,04)	-0,03 (0,04)	-0,02 (0,05)	-0,03 (0,04)
Constant	-0,45 (0,34)	0,42 (0,78)	0,32 (0,69)	-0,14 (0,18)	-1,29* (0,69)	-1,35** (0,63)	-0,35 (0,27)	0,16 (1,09)	0,17 (1,05)	-0,45 (0,45)	-1,17 (1,06)	-0,85 (0,95)
R^2	0,006	0,066	0,059	0,031	0,097	0,095	0,011	0,043	0,034	0,004	0,048	0,045
N	4371	4125	4190	4187	3871	4076	4166	3719	3962	4321	3925	4029

* p-value<0.1; ** p-value<0.05; *** p-value<0.01; **** p-value<0.001
Robust Standard errors after cluster correction in parentheses
Left out category for teacher education is the first one

Table 2. Fixed effects regression models. First-difference estimators.

	Mathematics – Physics			Mathematics – Biology			Mathematics – Chemistry		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
					Math teachers				
Education2	0,01 (0,06)	-0,02 (0,06)		0,08 (0,07)	0,01 (0,07)		0,04 (0,07)	-0,01 (0,07)	
Education 3	-0,05 (0,08)	-0,07 (0,09)		0,04 (0,09)	-0,05 (0,09)		-0,08 (0,08)	-0,10 (0,09)	

Experience_3-10	0,54**** (0,14)	0,29* (0,16)		0,12 (0,13)	-0,15 (0,18)		-0,08 (0,25)	-0,26 (0,32)	
Experience_11-20	0,54**** (0,11)	0,23* (0,13)		0,14 (0,13)	-0,15 (0,18)		-0,06 (0,26)	-0,25 (0,32)	
Experience_21+	0,47**** (0,11)	0,17 (0,13)		0,11 (0,12)	-0,19 (0,17)		-0,18 (0,25)	-0,38 (0,32)	
Sex (teacher, 1=female)	0,12 (0,18)	0,18 (0,20)		0,14 (0,17)	0,11 (0,18)		0,10 (0,16)	0,21 (0,15)	
Minutes teaching		0,00 (0,00)	0,00 (0,00)		0,00 (0,00)	0,00 (0,00)		0,00 (0,00)	-0,00 (0,00)
Homework (high)		0,05 (0,05)	0,05 (0,05)		0,02 (0,06)	0,02 (0,06)		0,01 (0,06)	0,02 (0,06)
TP_ repetitive		-0,29 (0,18)	-0,27 (0,18)		-0,28 (0,20)	-0,33* (0,18)		-0,23 (0,21)	-0,20 (0,21)
TP_understanding and interpretation		0,28 (0,24)	0,34 (0,23)		0,43* (0,25)	0,30 (0,23)		0,06 (0,26)	0,08 (0,25)
TP_meta skills		0,18 (0,23)	0,12 (0,22)		0,22 (0,24)	0,24 (0,22)		0,50** (0,25)	0,49** (0,23)
TP_group work		-0,21 (0,18)	-0,24 (0,18)		-0,21 (0,19)	-0,24 (0,17)		-0,33* (0,18)	-0,42** (0,17)
TP_frontal (%)		-0,04 (0,03)	-0,01 (0,03)		-0,01 (0,03)	-0,02 (0,03)		0,03 (0,04)	0,03 (0,04)
TP_individual work (%)		0,00 (0,01)	0,00 (0,01)		0,00 (0,01)	0,00 (0,01)		0,01 (0,01)	0,01 (0,01)
TP_control (%)		0,00 (0,01)	0,01 (0,01)		-0,00 (0,01)	-0,00 (0,01)		0,01 (0,01)	0,01 (0,01)
TP_senseless spending of time (%)		0,00 (0,01)	0,01 (0,01)		0,01 (0,01)	0,01 (0,01)		0,00 (0,01)	-0,00 (0,01)
		Physics teachers			Biology teachers			Chemistry teachers	

Education2	-0,07 (0,06)	-0,07 (0,07)		-0,00 (0,06)	-0,00 (0,06)		0,04 (0,07)	0,08 (0,07)	
Education 3	0,05 (0,10)	0,13 (0,11)		0,01 (0,11)	0,03 (0,12)		-0,15 (0,10)	-0,17 (0,10)	
Experience_3-10	-0,15 (0,14)	-0,04 (0,14)		-0,28* (0,15)	-0,28 (0,17)		-0,44 (0,27)	-0,47 (0,37)	
Experience_11-20	-0,13 (0,12)	0,00 (0,12)		-0,30** (0,14)	-0,33** (0,15)		-0,22 (0,24)	-0,34 (0,35)	
Experience_21+	-0,13 (0,12)	0,00 (0,12)		-0,30** (0,13)	-0,36** (0,15)		-0,26 (0,24)	-0,39 (0,35)	
Sex (teacher, 1=female)	-0,10 (0,08)	-0,05 (0,07)		-0,02 (0,02)	-0,03 (0,04)		-0,16 (0,13)	-0,25** (0,10)	
Minutes teaching		0,00 (0,00)	0,00 (0,00)		-0,00 (0,00)	-0,00 (0,00)		-0,00 (0,00)	-0,00 (0,00)
Homework (high)		0,07 (0,06)	0,08 (0,06)		-0,15* (0,08)	-0,12 (0,08)		-0,02 (0,08)	0,01 (0,07)
TP_ repetitive		-0,25 (0,16)	-0,33** (0,15)		-0,16 (0,22)	-0,17 (0,21)		-0,64**** (0,19)	-0,55*** (0,20)
TP_understanding and interpretation		0,46 (0,31)	0,72** (0,29)		0,09 (0,22)	0,04 (0,20)		0,38 (0,26)	0,23 (0,25)
TP_meta skills		-0,09 (0,21)	-0,11 (0,19)		0,57** (0,27)	0,46* (0,25)		0,04 (0,21)	-0,03 (0,22)
TP_group work		-0,01 (0,22)	-0,14 (0,19)		-0,02 (0,18)	-0,01 (0,19)		-0,12 (0,17)	-0,09 (0,17)
TP_frontal (%)		0,01 (0,03)	0,00 (0,03)		-0,02 (0,03)	-0,03 (0,04)		-0,03 (0,03)	-0,02 (0,03)
TP_individual work (%)		0,00 (0,01)	0,00 (0,01)		-0,01 (0,01)	-0,01 (0,01)		0,00 (0,01)	0,00 (0,01)
TP_control (%)		-0,00 (0,01)	-0,00 (0,01)		-0,00 (0,01)	-0,01 (0,01)		-0,01 (0,01)	-0,01 (0,01)

TP_senseless spending of time (%)		0,01 (0,02)	0,01 (0,02)		-0,01 (0,02)	-0,01 (0,02)		-0,03* (0,02)	-0,02 (0,02)
Sex (student, 1=female)	0,50**** (0,04)	0,47**** (0,04)	0,48**** (0,04)	0,05 (0,04)	0,04 (0,04)	0,04 (0,04)	0,17**** (0,04)	0,15**** (0,04)	0,15**** (0,04)
Constant	-0,66**** (0,19)	-0,32 (0,74)	-0,43 (0,78)	-0,06 (0,25)	0,50 (1,11)	0,50 (1,01)	0,30 (0,38)	0,74 (1,11)	-0,08 (0,91)
R^2	0,067	0,081	0,079	0,007	0,026	0,018	0,017	0,042	0,03
N	4104	3580	3835	4083	3488	3796	4238	3710	3840

* p-value<0.1; ** p-value<0.05; *** p-value<0.01; **** p-value<0.001
Robust Standard errors after cluster correction in parentheses
Left out category for teacher education is the first one

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