THE EFFECT OF TEACHER QUALITY ON STUDENT PERFORMANCE – THE PROFESSIONAL DEVELOPMENT OF SUBJECT KNOWLEDGE AND PEDAGOGY – PISA 2018 AND TALIS 2018

In this paper the effect that teacher quality has on student performance is studied. Contemporary literature indicates that an useful tool to improve teacher quality is professional development. The data sets of PISA and TALIS enabled me to use school-level data on students, schools and teachers to identify the effect that professional development training of teachers has on student performance. I looked into the reading, mathematics and science performance score of students to check whether students significantly scored lower when their teacher stated that he or she need professional development or significantly scored higher when their teacher took any professional development training in the last 12 months. An OLS regression was run to estimate these effects. The results indicate that mathematics students perform worse when their teacher stated that he or she need professional development. No significant effects were found for the other subjects. When it comes to whether the teacher received professional development training a positive effect is observed for reading performance, although this effect is not very significant (p-value < 0.1). Interaction effects suggest that new teachers benefit more of professional development training than more experienced teachers. Whether this teacher is in a rich or poor country or is teaching on a private or public school does not seem to matter, since no significant effects were observed. Due to the fact that the data did not allow to link teachers to their students, averages on teacher characteristics are taken on school level. This is a limitation to this study, since it leads to less accurate estimations. Future studies could look into this.

Master thesis in International Economics.

Student: Luc Boelhouwers

Student number: 387754

Supervisor: Laura D. S. Hering

Date: 15 November 2021

Contents

1. Introduction

“Give a man a fish and you feed him for a day. Teach a man to fish and you will feed him for a lifetime”. This saying has been widely used, mostly in non-scientific manners. In a superficial way, it does hold some truth. Ever since the beginning of researching the effects of education, it is generally agreed upon within the scientific society that educating the masses leads to significant social and economic benefits. In addition to the monetary gains achieved by students, significant public gains are also achieved (Bowen, 2018). The United Nations has put ‘the achievement of education’ as the second goal after eradicating extreme poverty and hunger in the Millennium Development Goals set in 2000. These goals are also embedded in the 2015 UN Sustainable Development Goals.

Besides the availability of education, the quality of education is also important, since it leads to additional significant gains of individuals and the general public. This relationship has been found by Hanushek and Kimko (2000) in which a higher quality of education led to an increase in national GDP growth. Therefore, “how to teach a man to fish” is also of major importance. Teacher quality is one of the main drivers of the quality of an educational institution. Therefore, policymakers see teacher quality as a major key in improving student performance. In this paper the main research question is what the effect of teacher quality is on student performance.

To answer this question, I first look into the existing literature on teacher quality. The first study with a significant sample size was from Coleman et al. (1966). They studied the determinants of student performance, which are student (background and environment), school and teacher characteristics. The findings suggest that student performance is only affected by student characteristics, thus these factors lay outside school premises. On the contrary, some researchers suggest that school characteristics do have an effect on student performance, but are also heavily dependent on the student background. (Lee, Bryk, & Smith , 1993). Next to the above mentioned studies, many other studies have been done. However, these studies have not led to conclusive results with regards to teacher and school characteristics on student performance.

Thus, researchers have not been able to find conclusive evidence on the characteristics that influence student performance, especially when it comes to teacher quality. Ambiguous findings across studies indicate that not a single model, nor different identification strategies have consistent findings. In these, somewhat older, studies, researchers tend to use qualification, years of experience and background as an equivalent of teacher quality. These characteristics are easily measurable and are, therefore, suitable for quantitative analyses, but they do not actually show what goes on in the teacher’s classroom. Therefore, these characteristics are inadequate substitutes

for teacher quality. This might be the reason for the various ambiguous and contradicting results of these older studies

However, trends are emerging in more recent studies that suggest that teacher quality does have an influence on student performance. In these studies, the focus is on good teacher practices, including classroom practices, planning, instructional delivery and classroom management. More contemporary research on these aspects of teacher quality shows that teachers who used good teacher practices led to improved student performance. Therefore, high quality teachers distinguish themselves, not by education or years of experience, but mainly through the use of good teacher practices. Improving these teacher practices would in turn lead to improved teacher quality. To improve teacher quality through teacher practices, many schools support professional development sessions. Professional development enables that teachers can learn new good teaching methods via internet courses, group sessions with peers within outside the school or sessions that are ran by institutions which individual teachers can apply for.

In this research I try to find the effect of professional development on student performance in two ways. Firstly, student performance is linked to teachers who answered to what extent they need professional development. In other words, what is the effect on student performance when teachers feel that they need professional development. Secondly, I link student performance to teachers who have received any form of professional development in the last 12 months. This leads to the following, more specific, research question: what is the effect of professional development of teachers on student performance?

I analyse this question using data on student and teachers coming from the OECD PISA and TALIS programs involving around 27,000 students and 5,878 teachers in 937 schools from 8 countries. Information on student performance, teacher and school characteristics will be combined. The data involves micro-level data on students, teachers and schools. Students participating in PISA took a test to assess their proficiency in reading, mathematics and science. These results are substitutes of student performance. This test is generalized for all participants, meaning that every student in every country received the same test, besides the fact that they were translated into language that is spoken locally. This makes it a suitable variable to compare students across schools, teachers and countries.

A side note is that the student performance scores are not the actual scores of the students. The performance tests were extensive covering several aspects of reading, mathematics and science. Since these tests are too extensive to be conducted entirely by each student, only a portion was conducted by each student. Based on how a student performed on his or her test, an estimate was

given on how this student would have performed on the entire test. These estimates are called plausible values, and the PISA dataset included ten plausible values for each student. These plausible values were drawn from a distribution based on how the student performed on its own test.

Teachers and students are linked on school level, meaning that students cannot be assigned to one specific teacher. Therefore an average is taken of the teachers in schools that had at least two teachers in one subject area. For schools with only one teacher participating in the survey, it is assumed that he or she is the teacher of the students.

To answer the main research question the independent variables are (1) does the teacher need professional development classes in the areas of subject knowledge and pedagogy and (2) did the teacher participate in professional development classes over the last 12 months. With regards to the first question, teachers self-reported their need of professional development in the areas of subject knowledge or pedagogy. The outcomes range from 0 to 3 on a Likert Scale, implying the severity of their need. The answer to the second question is a simple 'yes' or 'no'. Since the combination of data sets of student, teachers and schools provides much additional data, this research controls for other important factors affecting student performance.

Data including the student performance scores, teacher's participation in professional development, teacher's need for professional development and control variables are estimated in an OLS regression model including country fixed effects. According to PISA data manual, the previously mentioned ten plausible values should be treated as one dependent variable. But since these ten plausible values were drawn from a distribution, simply taking an average of the these values would give inaccurate values. To address this, Kevin MacDonald, a PISA employee, developed a STATA module to correct for this. This module also adds weights to students, since the sample is not randomly drawn. This will be elaborated on in section 4, Methodology.

After running the regressions, ambiguous effects are found across the three different subjects; reading, mathematics and science. In the first regression the only significant effect is the effect of subject knowledge and classroom management student mathematics performance. It shows that students perform worse when a teacher needs more professional development in these areas. For reading and science, such effects were not found. Next, a regression was run to measure the effect of teachers who received professional development training on student performances. Only for reading performances an effect was found with a low significance level (p-value < 0.1). For mathematics and science performances no significant effects were found. Another regression was run including interaction effects. These results suggested that less experienced teacher might benefit more from professional development than more experienced teachers.

This research was prone to some study limitations. Since both questionnaires contain self-reported data, this data does include biases. An endogeneity problem can occur, which means that teachers who see that their students perform badly, tend to fill in that they might need more professional development in several ways. Another bias is the social desirable bias, which makes the person taking the questionnaire filling in the more socially desirable answers. This could lead to an underestimation of our research, since teachers might tend to fill in that they do not need as much professional development as they truly need.

2. Literature Review

Background

Since the beginning of studying the effects that schools have on student performance, researchers have not been able to find a large positive relationship between the two. Teachers form a large component of the total school resources, since expenditures on teachers are a significant portion of the total school expenditures (school resources). Schools with many school resources tend to employ teachers of high quality. Intuitively, employing capable teachers would result in better student performance within the school and therefore teacher quality might be a significant contributor to student performance.

Although this seems self-evident, one of the earliest and most influential studies in this regard, which is the Equality of Educational Opportunity Study (Coleman Report) has not been able to find this effect (Coleman , et al., 1966). Since this research was conducted as a part of the Civil Rights Act of 1964, the emphasis of this research is on the differences in racial classes with regards to schooling. Trying to find what schools can do to improve student performance, this research simultaneously gives interesting insights into the effect of student background on student performance. This study, which included 500,000 students over 3000 schools, used a classic production function to find the factors that have an effect on student performance. An Ordinary Least Squares (OLS) regression analysis was performed. The analysis included expenditures per student, characteristics of the staff (teachers), characteristics of fellow students and characteristics of the environment. Coleman, et al. (1966) concluded that no significant effect was found between school resources and student achievement when student background was included. Meaning student background is the main significant contributor to student performance, suggesting that school resources and characteristics of the teachers do not play an important role in student performance.

Numerous additional studies have been conducted. These studies focused on different aspects of the Coleman Report. By studying the effect of school characteristics on student performance, these studies found that strong administrative leadership, student monitoring and the orderly and quiet natured schools do have a significant effect on student performance (Edmonds, 1979; Brookover & Lezotte, 1979). The studies done by Edmonds (1979) and Brookover and Lezotte (1979) were redone with a larger sample size by Lee, Bryk and Smith (1993). They confirmed that leadership qualities, student monitoring, and a disciplinary environment have a positive effect on student performance. On top of that, they found that both school and class size have a significant effect on student performance. However, these effects remain small when student background is included in the

analysis. These small effects suggest that student background is the main contributor, opposed to school characteristics.

Numerous other studies have been conducted in this regard. Hanushek (1997) reviewed several of these studies in which he summarized the effect that school, teacher quality and student characteristics have on student outcome. He made up a balance of the studies. This balance contained significant and non-significant effects, and positive and negative effects. By doing this, he tried to find an overall trend among these studies. In his research he focused mainly on teacher-pupil ratio, teacher education, teacher experience, teacher salary and expenditure per pupil. Over 377 estimates from 90 studies related to school resources and teacher quality showed no consistent relationship to student performance. Contradicting outcomes were found, some showing significant negative and positive effects, while others found insignificant negative and positive effects. Conclusive, consistent and large evidence have not been found among these studies.

Teacher quality

As mentioned before, teacher quality may play an important role in student performance. Going back to the Coleman Report (1966), Coleman used the following seven characteristics to find any variation in student outcome: teacher experience, educational attainment, vocabulary skills, ethnicity, parents' educational attainment, if the area in which he teaches is also the area in which he grew up, and the teacher's attitude toward teaching middle class students. The results showed that these characteristics make up less than 1% of student test score variation.

Teacher quality seems hard to define and even harder to measure. An influential paper on the link between teacher quality and student performance suggests a framework of determinants of teacher quality (Goe, 2007). Goe suggests that teacher quality is composed of three main aspects, which are teacher qualifications, teacher characteristics and teacher practices. Qualifications include teacher's education and experience. Characteristics apply to attitudes, beliefs, self-efficacy, age, race and gender. Teacher practices involve classroom practices, planning, instructional delivery, classroom management and interactions with the students. The first two main aspect are relatively easy to observe and quantify. Teacher practices, however, are much harder to observe, especially on a large-scale basis. Observing these practices bring major advantages into giving insight regarding teacher quality and its effect on student performance. Even when teachers share similar qualifications, they can have different teaching methods. Therefore, qualification or education cannot be a measurement of teacher quality on its own. Much more insight is given when the interaction between teacher and student is observed and subsequently linked to the student's performance. Linking teacher's questioning strategies to student performance is an example of

classroom practice mechanisms. An overview of the three mechanisms is given by Goe (2007) in figure 1.

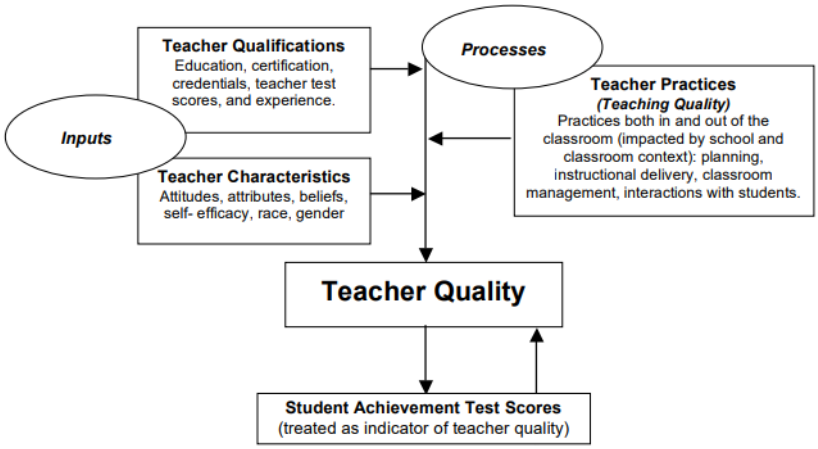

Figure 1 Graphic representation of a Framework for Teacher Quality (Goe, 2007)

Several of the abovementioned teacher practices have been tested in recent literature. Hereby, researchers focussed on what are considered good practices that are linked to better student learning and thus could lead to better student performance. Although this study does not look into teacher practices, it is important to mention the importance of teacher practices and the hardships that comes with studying these practices, namely because further on, this study also discusses how to improve these teacher practices. Several studies express the importance of the effect that teacher practices have on student performance.

Teaching practices that included student co-operation in groups, oral presentations, writing reports, student explaining the solutions to the rest of the class (Frome, Lasater , & Cooney, 2005) and when students worked on projects in groups and solved practical problems, whether the teacher checked and discussed homework (Marcoulides, Heck, & Constantinos, 2005) resulted in higher student performance, compared to teacher who did not use these practices. In a study that evaluated teachers on the four following aspects: planning and preparation, classroom environment, instruction, and professional responsibilities, researchers found that student performance increased when teachers scored better on these aspects (Heneman III, Milanowski, Kimball, & Odden, 2006). A study that looked into high-performing high-poverty schools and the factors that distinguished them from low-performing high-poverty schools, researchers found that teachers that used frequented assessment and feedback, delivering instructions on learning goals and assessment, participating in collaborative decision making and continuing professional development resulted in better student performance (Kannapel, Clements, Taylor, & Hibpshman, 2005).

With regards to the latter, teachers that took professional development classes were studied by Wenglinsky (2002). Professional development classes in high-order thinking resulted in increased student performance. High order thinking focuses on problem solving and critical thinking rather than reproductive thinking and facts learning.

Previous large-scale researches focus on easily measurable variables, i.e. qualification, teachers' test scores (Ferguson R. F., 1991; Ferguson & Ladd, 1996), experience (Gerritsen, Plug, & Webbink, 2017), race (Hanushek, Kain, O'Brien, & Rivkin, 2005) and gender. Although these are also important variables in determining teacher quality, it hardly gives a view on the actual practices within the classroom.

These studies show us that certain aspects of teaching methods have a significant effect on student performance. However, determining the quality of a teacher classroom practices is high-intensive research. Researchers or associates need to go and actually see the teachers within the classroom to assess which practices they use and how good they implement them. A more practical way to look into teacher quality is to check whether a teacher participated in activities that should have improved his or her teaching practices and, thus, teacher quality. These activities are called professional development, which have already been discussed, briefly.

Professional development

In order to improve teaching quality within the classroom, schools promote the professional development of their teachers. During these professional development classes, teachers learn new strategies, for example, teaching methods, individualized learning methods, assessment methods, student behavior methods. In turn the professional development may lead to the improvement of student performance.

A study by Cohen and Hill (1992) suggested that teachers who participated in professional development classes actually changed their classroom practices and in turn positively impacted student performance. The same results have been observed by Wallace (2009) who also found significant effects. These effects, however, are small in contrast to the results shown in the study by Cohen and Hill. Opfer and Pedder (2011) concluded in their research that professional development of teachers lead to changes in classroom practices and result in increased student performance. They also found that teachers from within the same school join the professional development classes collectively, the changes in classroom practices are greater than teachers that joined professional development training individually.

The aforementioned studies show that professional development have a significant effect on student performance. However, professional development has not always proven to be effective.

The next two examples show that different professional development programs can have different effects.

Darling-Hammond and Richardson (2009) studied the Kennedy High School and its professional development designs. Since the algebra performance of its students were too low, teachers took a two-day four-hour workshop by experts to improve their teaching techniques. Immediately after these workshops teachers were confident and said they would incorporate the new strategies into their class practices. After a few months, a session was planned to discuss how the implementation worked out. Almost every teacher confessed they had trouble implementing the newly learned techniques and recent student algebra tests showed no improvement.

In the next example a vastly different approach was used when teachers took professional development classes. Pine Hills' teachers were able to create their own professional development plan to improve their students' performance. Several teachers were sent to a three week summer institute to improve their teacher practices. Instead of scheduling a couple of days for professional development purposes, teachers came together an hour every week to discuss methods and share findings based on experiences in their classes or self-conducted research. During these sessions teachers developed an improved reading instruction. Grades shifted up significantly when these professional development sessions were introduced.

The suggestion that professional development is not necessarily a good thing has also been shown by Telese (2012). He also makes a distinction in receiving too much professional development sessions and too few professional development sessions. In his study, with over 100,000 students in the United States, he found that teachers who only received professional development to a small extent actually performed better afterwards than teachers who received moderate to extensive professional development. He also suggested that professional development should *"hinge"* on topics that enhance teacher's subject knowledge and teacher's pedagogical knowledge.

Teacher's subject knowledge and teacher pedagogical knowledge are important factors in improving teaching practices and thus teaching quality.

Subject knowledge

As Telese (2012) suggested subject knowledge is an important factor in the success of teacher's practices. After all, how can a teacher teach a subject well with hardly having any knowledge on the topic he or she is teaching. This seems self-evident, but research has not always found supporting evidence. Similar to the previously mentioned study of Hanushek (1997), Byrne (1983) reviewed the results of 31 studies related to subject knowledge. When subject knowledge is linked to student performance, 17 studies showed a positive effect, whereas 14 showed no relationship. Byrne

mentioned that of these 14 studies the variation in teacher knowledge was so low, that insignificant effects were expected.

Hawk, Coble and Swanson (1985), found that (partially) certified teachers have a significant positive effect on student achievement. On top of that, they found that fully certified teachers have larger significant effect on student performance in comparison to partially certified teachers. These gains were larger in algebra lessons than for general mathematics. Meaning, subject knowledge has a greater effect on student performance when a subject is more complex. This study was conducted using binary variables. Either a teacher was fully certified, partially certified or not certified.

Another study was conducted following a similar analyses with continuous variables using the total credits teachers gained during their education in field they are teaching now. Results showed that the number of credits had a positive effect on student performance, but that this effect had diminishing returns when the number of credits increased (Begle & Geeslin, 1972).

Two large survey based studies have been conducted on subject knowledge of a teacher on student performance. Monk (1994) studied high school students in 10^{th}, 11^{th} and 12^{th} grade on their mathematics and sciences scores, and made them fill out a surveys about their backgrounds. Teachers in these subjects were also surveyed about their education level and background characteristics, such as experience and age. Teachers that took more intensive college level mathematics and science courses on both subject knowledge and pedagogy led to higher student performance on the tests. Another research was conducted by Goldhaber and Brewer (1996), the solely researched mathematics students and teachers in 10^{th} grade. The results are similar to Monk's (1994) research.

Metzler and Woessmann (2012) found a significant effect of teacher subject knowledge on student achievement using data on math and reading achievement of 12,000 6th-grade students and their teachers in Peru. When identifying the causal effects of teacher characteristics on student achievement, problems with unobserved student and teacher characteristics and non-random selection of classrooms biased the estimates. Using student and teacher fixed effects led to an unbiased estimation of the results.

Pedagogy

In the previous subsection literature has been discussed with regards to subject matter knowledge, only briefly mentioning the pedagogical skillset. Having knowledge of a subject forms the basis of teaching it to other people. One cannot, simply, teach things to other people without having the knowledge. The ability to teach in several ways is different than having ample knowledge about a subject. Knowing how to explain things in effective ways might be as important as having knowledge

about a subject. From this it can be derived that subject knowledge and subject pedagogy are going hand in hand in relation to student performance. The next mentioned studies indicate that subject related pedagogical education would result in increased student learning and therefore student performance.

As Byrne (1983) mentioned in his work: *"If the teacher is to teach fractions, then it is knowledge of fractions and perhaps of closely associated topics which is of major importance."* Knowing different teaching strategies to being able to explain and for the student to understand fractions can be in significant importance. Besides knowing fractions, being able to explain them is equally important. Several researches have shown that professional development with regards to subject specific pedagogy may have a positive effect on student performance. (Wiley & Yoon, 1995).

Darling-Hammond (2000) suggested in her literature review that different groups of students need different teaching methods. Teachers who learned to teach different groups of students would therefore have different teaching methods. They found that teachers who learned how to teach different groups of students have a positive effect on student performance in comparison to students whose teacher did not learn this.

Specifically focusing on reading achievements of students. The National Assessment of Education Progress noted that student performance on reading are positively affected by teacher that received specific kind of learning opportunities. These learning opportunities specifically included professional courses in literature-based instructions. In other words, the teachers were taught how to give instructions to different groups of students (National Center for Education Statistics, 1994).

In relation to subject knowledge, Marzano (2003) stated that subject knowledge is positively related to student performance up to a certain point. Teachers who have more pedagogical knowledge have a positive effect on student performance. On top of this, pedagogical knowledge is more often found in more experienced teachers who received educational training, than teachers who possessed lots of subject knowledge but received less education training.

Doherty and Hilberg (2007) studied the effects of 5 standard effective pedagogy measures on students. These standard effective measures were, joint activities, development of competent language use, connecting new information to prior knowledge or experiences, complex thinking and dialogic teaching by having goal-directed instructional conversations. Positive significant effects were found when teachers transformed their classroom practices according to the five standards. The most significant gains were observed for low-English-proficient students. This study, however, had a small sample size with only 23 teachers and 394 students.

This last study by Doherty and Hilberg is important, because they show that by acquiring pedagogical skills through professional development changed classroom practices, which in turn led to increased student performances. A similar approach will be used in this study, in which I check whether professional development has an effect on student performances. In this study, a larger sample size is used.

3. Data

In this study, I make use of two datasets provided by PISA and TALIS. Both these surveys have been conducted in 2018.

PISA 2018

Programme for International Student Assessment (PISA) is a student performance test which measures individual achievement in reading, mathematics and science, that occurs every three years. The program assesses 15 year old boys and girls. The tests are computer based with the assessment lasting two hours for each student.

On top of the assessment, students were asked to fill in a 35 minute survey, that asks student several questions on their attitudes and motivation, family background, their homes, social environment, perceived teacher-engagement. 600,000 students completed the assessment and questionnaire, representing 32 million 15 year old students from over 79 participating countries.

Using the PISA dataset, many researchers studied the effects of student background (Dincer & Uysal, 2010), social economic status of the school (Perry & McConney, 2010), student wellbeing (Govorova, Benitez, & Muniz, 2020) and the usage of computers (Bielefeldt, 2005) on student performance. These studies were primarily focused on the students environment and how the student perceived his or her school and teachers.

In this paper, this data set is primarily used to extract data of student performance scores on reading, mathematics and science. On top of that, this data sets gives us information about the student's social-economic status, the education of his or her parents, age, gender and in which grade the student participates.

Another part of the PISA 2018 program is a questionnaire handed to school principals. This paper used the data on questions about the size of the school and the town and whether the school is a publicly or privately owned.

TALIS 2018

In order to conduct this study, teacher data is used from the Teaching and Learning International Survey (TALIS). This questionnaire asks teachers and again school principals about the teachers background, educational level, teaching beliefs and practices, the assessment of their work, questions about their professional development, classroom experience, and numerous other questions.

TALIS results are used in studies involving, teachers job satisfaction (Kasalak & Dagyar, 2020), professional development of teachers on instructional quality (Dogan & Yurtseven, 2018), determinants on classroom discipline (Lopes & Oliviera, 2021).

TALIS provides various interesting insights about the many aspects of being a teacher. In this research the main question at hand is the data on whether the teacher participated in professional development classes in the last 12 months and if the teacher thinks he or she needs professional development. Data on teacher's age, teacher's experience, teacher's education, and class size is also used

Combining data sets

As is stated above, the data sets are often used to study certain aspects of either students or teachers, without being able to examine what effects teachers have on students. In this paper, I combine both data sets to examine this effect.

The OECD organize both PISA and TALIS surveys and since both surveys are conducted in the same year, it is interesting to combine them. In this paper, I combine the two data sets on school level. A school that has participated in PISA received a unique school number. In TALIS they labeled the school that participated in PISA with the same unique school number, enabling researchers to combine the two data sets.

A drawback is that, teachers have not been assigned to the very classrooms in which PISA participating students are present. To overcome this issue, an average is taken on school level in case the school has multiple reading, mathematics or science teachers teaching these classes. This micro-level data is very useful to measure the effects of teacher quality on student performance.

Various studies were conducted using both datasets. Delprato and Chudgar (2018) used the PISA 2012 and TALIS 2013 link to study the difference in performance of teachers in private and public schools and the effect it has on student performance. In their research, Delprato and Chudgar averaged teacher characterstics on school level to measure the effect private schools have on student performance. One of the central concerns of isolating the private school effect is the selection bias. Private schools often select already well performing students. They indentified three variables in which schools can be distinguised, which are teacher autonomy, teacher sanction and teacher support. The researchers, then, compared public schools to private schools, if they showed similarities between these three variables. The difference in student performance is the "private school effect". One of the shortcomings of their research that only three countries are included in their analysis. The three countries used were Australia, Spain en Portugal, because they had important similarities and differences, making it ideal to compare them. By using PISA 2018 and

TALIS 2018, this research is expanded to the following eight countries: Argentina, Australia, Colombia, Czech Republic, Denmark, Georgia, Malta and Turkey.

Another study using PISA 2012 and TALIS 2013 data looked into teacher participation, principal commitment and school responsibility on student performance on school in Singapore and found a significant relationship (Huang, Tang, He, & Li, 2019).

The data set in this study consists of 26,980 students participating in PISA corresponding with the 5,878 teachers in TALIS. These students and teachers are divided over 937 schools in 8 countries.

Variables

Dependent variable

For the dependent variables, this research will use the student performance scores in reading, mathematics and science.

The student performance scores are not the actual scores of the students. The performance test covers several different aspects of reading, mathematics and science. Since these tests are too extensive to be conducted entirely by each student, only a portion was conducted by each student. Student scores were later given based on how they performed on this small portion. To get a better image on this a clearer example is provided. Imagine the test is split in 8 blocks, ranging A to H. Students took different parts of the entire test, meaning student 1 took a tests containing block A and B and student 2 took a test containing block B and C and student 3 took a test containing Block C and D, etc. Based on how a student performed on his or her test, an estimate was given on how this student would have performed on the entire test. These estimates are called plausible values, and the PISA dataset included ten plausible values for each student. These plausible values were drawn from a distribution based how the student performed on its own test. The plausible values have a value between 100 and the 850. The ten plausible values of each subject are shown in appendix 1.

The PISA manual warns that using PV's needs careful treatment (OECD , 2009). Taking an average of these ten plausible values is not recommended since it leads to biased estimations. Kevin MacDonald's module is used to correct this (Macdonald, 2019). This module, by assigning variance estimators, treats the 10 plausible values as one dependent variable and, thus corrects for the random error variance components.

Independent variables

The main question of this research is (1) what is the effect is of teacher subject knowledge and pedagogy on student performance and (2) what is the effect of a teacher having received a professional development training in the last 12 months. In the TALIS questionnaire the teacher is asked four questions on the following; *"please indicate the extent to which you currently need*

professional development.", with regards to (1) knowledge and understanding of my subject field, (2) pedagogical competencies (3) knowledge of the curriculum and (4) classroom management in teaching my subject field. The possible answers to these questions are; (0) not at all, (1) low level of need, (2) moderate level of need and (3) high level of need. The answers to these four questions are given separately. The TALIS program constructed a scale based on the answers given by the teacher on these four questions. If the teacher answered that he or she has a high level of need of professional development to all four questions the scale notes a higher score than a teachers who answered not at all, or low level of need. This scale ranges from 4.7 to 16.2. For the second question the teacher answers a simple yes or no.

To make sure the effect of an omitted variable bias is being minimalized, several control variables of importance are added. This research includes both student control variables, teacher control variables and school control variables. Student control variables include; (1) gender of the student, (2) grade of the student, (3) age of the student (this ranges from 15 years and 2 months to 16 years and 3 months), (4) dummy variables for each level of highest educational level accomplished by the parents and (5) Social Economic Score Index (HISEI). Teacher control variables include; (1) average age of teacher by subject, (2) average education level of teacher by subject, (3) average years of experience and (4) average class size by subject. School control variables include; (1) public school, (2) size of the school and (3) whether the city is larger than 100,000 inhabitant. These variables will be discussed in the next subsection.

Descriptive statistics

Student characteristics

Table 1 Student Characteristics Descriptive Statistics

	N	Mean	Std. Dev.	min	max
Female	26980	.5	0.500	0	1
Grade	26980	-.058	0.636	-3	2
Age	26980	15.794	0.290	15.25	16.33
Highest Schooling of Parents	26097	4.405	1.689	0	6
Social Economic Status Index	24778	48.024	23.498	11.01	88.96

As can be seen in the descriptive statistics, Female is a dummy variable that takes the value of 1 if the student is female.

Grade represents the grade the student takes. The students are all around the same age, but the grade they take might differ. When a student repeats a grade once, his grade would be -1 in this example. If a student skips a grade, his grade would be 1. When the grade equals zero, the student neither skipped a grade, nor skipped one. This variable is used as a substitute for previous

performance of the student, because bad performance would result in a student repeating a grade. And very good performance would results in skipping a grade.

Age, is the age of the student. It lies between 15.25 and 16.33 years old.

The Highest Schooling of Parents notes the highest schooling one of the parents have received. With 0 being no schooling. The higher the score, the higher level of education one of the parents have received. Many countries use different kind of education systems and therefore level of educations might have a different meanings across countries. To tackle this ISCED is used. ISCED is an internationally used system, which grades the level of education uniformly across the world. This makes it possible to conduct the analyses across countries.

The variable Social Economic Status Index indicates the SES of the family of the student. 11.01 means the family of the student is extremely poor and 88.96 very wealthy. This value is based on questions students answered in the questionnaire. These questions include, occupation of parents and items the family possess, like a computer, dishwasher, the amount of cars etc.

School Characteristics

Table 2 School Characteristics Descriptive Statistics

	N	Mean	Std. Dev.	min	max
Public School	894	.773	0.419	0	1
School Size	874	776.175	701.458	28	6745
Large Village	937	.51	0.500	0	1

With regards to the school characteristics, Pubic School takes the value of 1 when the school is a public school. School Size is the number of students that are enrolled at the school. Large Village takes the value of 1 when the city in which the school lies has more than 100,000 inhabitants.

Teacher Characteristics

Table 3 Reading Teacher Descriptive Statistics

	N	Mean	Std. Dev.	min	max
Age of the Teacher	2078	3.81	0.915	1.5	6
Education of the Teacher	2077	5.388	0.565	2	7
Years of Experience	2078	16.226	8.150	0	46.5
Class size	2071	26.662	8.895	2	90
Need for PD in Subject Knowledge	2075	1.019	0.690	0	3
Need for PD in Pedagogy	2073	1.067	0.669	0	3
Need for PD in Curriculum knowledge	2075	.951	0.687	0	3
Need for PD in Class Management	2075	1.079	0.699	0	3
Scale of Need for PD	2075	9.373	1.322	4.719	14.376
Received PD	2076	.906	0.202	0	1

Table 4 Mathematics Teacher Descriptive Statistics

	N	Mean	Std. Dev.	min	max
Age of the Teacher	1730	3.873	0.897	2	6
Education of the Teacher	1729	5.34	0.609	1	7
Years of Experience	1730	16.791	8.523	0	56
Class size	1722	27.872	9.255	2	90
Need for PD in Subject Knowledge	1726	.937	0.697	0	3
Need for PD in Pedagogy	1725	1.085	0.702	0	3
Need for PD in Curriculum knowledge	1723	.879	0.702	0	3
Need for PD in Class Management	1726	1.117	0.748	0	3
Scale of Need for PD	1726	9.283	1.353	4.719	14.216
Received PD	1733	.9	0.214	0	1

Table 5 Science Teacher Descriptive Statistics

	N	Mean	Std. Dev.	min	max
Age of the Teacher	2066	3.997	0.836	2	6
Education of the Teacher	2066	5.501	0.585	1	7
Years of Experience	2065	17.524	7.962	0	49
Class size	2063	27.99	9.578	2	94
Need for PD in Subject Knowledge	2064	1.094	0.699	0	3
Need for PD in Pedagogy	2063	1.167	0.679	0	3
Need for PD in Curriculum knowledge	2062	.943	0.691	0	3
Need for PD in Class Management	2063	1.154	0.700	0	3
Scale of Need for PD	2064	9.371	1.285	4.719	16.172
Received PD	2067	.901	0.195	0	1

As mentioned before, students and teachers have been grouped by school. Meaning that every teacher in a school could not directly be linked to the student taking its classes. Since, in some schools more than one teacher in reading, mathematics or science participated in TALIS, averages have been taken of teachers teaching the same subject.

Average Age of the Teachers had been categorized, with the value 2 being younger than 30 and 6 being older than 60.

For Average Education of the Teacher, the ISCED levels are also used. One is the lowest form of education and a seven indicates the teacher owns a PHD degree.

For Average Years of Experience, an average is taken of the years of experience of the teachers teaching the subject.

Next is the Average Class size. This represents the average size of a reading, mathematics or science class.

Average Need for PD in Subject Knowledge and Average Need for PD in Pedagogy are the variables of interest. As explained before, the value of zero indicates that the teachers do not think he or she needs Professional Development in these areas. An 1 indicates a low level of need. A 2 indicates a moderate level of need and a 3 indicates a high level of need.

Average Need for PD in Curriculum knowledge and Average Need for PD in Class Management are included in the analysis, since they are components of the constructed scale. Discarding these two questions might lead to an incomplete picture whether a teacher needs professional development.

As explained before, the Scale of Need for PD is a scale that has been constructed based on the answers given to the questions whether the teacher thinks he need professional development in the areas of Subject Knowledge, Pedagogy, Curriculum knowledge and Class Management. This scale ranges from 4.7 to 16.2.

Average Received PD is the whether a teacher has participated in any kind of professional development activities over the last twelve months. This variables can take the value between 0 and 1, indicating the fraction of teachers within the school that participated in these activities. As has been done with all teacher variables, an average was taken on school level when more than one teacher was teaching reading, mathematics or science. This explains some observations being 0.5 or 0.666. It should be noted over 90% of the teachers have participated in professional development activities. Since this study has a large sample size, this should not be lead to any complications.

4. Methodology

Sampling

The sample is constructed using a two staged sampling procedure. Schools are drawn based on whether they cover the target population. Smaller schools mostly do not have the means to participate in PISA or TALIS program, especially in poorer regions. This means the schools are not drawn by random sampling. Namely, the schools are assigned probabilities of selection, that are based on the size of the schools. Because a probability has been used, computation of sampling weights is allowed. The sampling weight assure that the a school with many students has a fair representation in comparison to a school that has few students (Dincer & Uysal, 2010). Hereafter, the students are randomly drawn within the school. Since the school has not been drawn randomly, the student does not represent all students of its age group. To correct for this each student is assigned a sampling weight as has been described above.

Because the schools are not randomly drawn, student in one school might share some common factors of a student in another school. This could give an common error term shared by all students within a school. This error term cannot be ignored, since it would give biased estimations of the parameter of the variables.

Therefore, PISA recommends to usage of balanced repeated replication (BRR) to correct for this bias. By providing 80 subsamples via 80 different sampling weights, each estimation is repeated 80 times. Every parameter therefore, has 80 estimations and therefore a sampling distribution of the estimators can be drawn. In this study, a STATA module developed by Kevin MacDonald is used.

Ordinary Least Squares model

In Delprato and Chudgar's research (2018), they use an OLS regression to capture the effect public and private schools have on student performance. In this study, I will also use an OLS regression. It goes as follows:

Equation 1

$$Ys,t,c = \alpha + \varphi\ Need\ for\ Professional\ Development\ t,c + \beta\ XSTs + \gamma XSCs + \delta\ XTEt,c + \rho\ fe + \varepsilon s,t,c$$

Where, *Y* is the test performance of student taking a certain course. Hereby, *s* stands for the student taking course *c*, with teacher *t* teaching that course. The estimation is done via an OLS regression model. The parameter of interest is φ, where we are able to find the effect of the need for

professional development on subject knowledge and pedagogy on student performance. *Need for Professional Development* is the intervention variable that represents the teacher's need for professional development with regards to subject knowledge and pedagogy skills as has been described in the previous section.

XST is a vector of control variables for student *s*. *XSC* is a vector of school control variables of the school student *s* is enrolled in. *XTE* is a vector of control variables for the teacher t teaching course *c* in which student *s* is participating. "t" represents the teacher, who teaches course c to student *s*. $\rho\ fe$ is the country fixed effect term. In this regression equation the ε is the error term. α, β, γ, δ, ρ and φ are the parameters to be estimated. α is the constant term of the estimation.

Equation 2

$$Ys,t,c = \alpha + \theta\ Received\ Professional\ Development\ t,c + \beta\ XSTs + \gamma XSCs + \delta\ XTEt,c + \rho\ fe + \varepsilon s,t,c$$

The same equation is used when the effect of teachers who received professional development on student performance is estimated. In here, θ is the coefficient of interest. *Received Professional Development* is an average taken on school level when more than one teacher teaches a subject at school a school. Received Professional Development takes a value between 0 and 1. 1 states that 100% of the teachers received professional education and a 0 states that none of the teachers received professional education. All control variables in the previous regression will also be included in this regression.

Equation 3

$$Ys,t,c = \alpha + \theta\ Need\ for\ Professional\ Development\ t,c + \pi\ \ Need\ for\ Professional\ Development\ t,c\ *\ Interaction\ t,c + \beta\ XSTs + \gamma XSCs + \delta\ XTEt,c + \rho\ fe + \varepsilon s,t,c$$

Equation 4

$$Ys,t,c = \alpha + \theta\ Received\ Professional\ Development\ t,c + \pi\ Received\ Professional\ Development\ t,c * Interaction\ t,c + \beta\ XSTs + \gamma XSCs + \delta\ XTEt,c + \rho\ fe + \varepsilon s,t,c$$

To estimate the interaction effect between Need for Professional Development and OECD countries, Teacher Experience and Public School and Received Professional Development and OECD countries, Teacher Experience and Public School, equation 3 and 4 are used. π is the parameter of interest.

5. Results

Need for Professional Development

In this first subsection, the results of the Need for Professional Development variables are shown and discussed. As explained before, these variables were asked to the teacher about to what extent he or she would need professional development training in the following areas: subject knowledge, pedagogy, curriculum knowledge and classroom management.

Subject Knowledge is the actual knowledge the teacher has about the subject that he or she teaches to his or her students. A teacher must understand the subject and its concepts. The teacher is, also, able to structure the subject and develops factual knowledge about it. This is all to guide the student to a certain level of knowledge.

Pedagogy is the knowledge a teacher has on how the subject can be taught to the students. It can be very helpful for a student to understand the subject, when the teacher is able to explain certain aspects of a subject in several ways.

Curriculum knowledge is the knowledge a teacher has about the curriculum of the students. At the end of school year, students must have met the learning objectives to be able to go to the next grade. Teachers must know how to structure and organize classes to ensure that the students meet their objectives. This also includes the way how a teacher is going to assess the students to observe whether they have sufficiently knowledge on the subject.

To ensure that the teachers are able to teach the subject and meet the requirements set in the curriculum, a classroom must be organized, orderly and focused. This is called classroom management. A teacher who is not able to maintain order in a classroom might experience difficulties in transferring his or her knowledge. It is important that teachers focus on students compliance, but more contemporary views also suggest that teachers should focus on other aspects of classroom management, like behaviour (positive attitude), classroom activities and the use of useful and interesting study materials.

Based on these explanations, it is noticeable that these areas are overlapping and the lack of knowledge in one area might lead to a lack of knowledge in the other area. One of the assumptions for accurate estimations in an OLS regression is that no multicollinearity exists between two independent variables. Multicollinearity is when one independent variable is correlated to or dependent of another independent variable. For control variables, this is not an issue, but when using multiple experimental variables, this would result in inaccurate estimations. These four variables are, therefore, split and used in separate regressions.

Reading – Need for Professional Development

Table 6 Reading - Need for Professional Development

VARIABLES	Reading	Reading	Reading	Reading
Need for PD – Subject Knowledge, t, c	-1.571			
	(4.860)			
Need for PD - Pedagogy, t, c		1.519		
		(5.362)		
Need for PD - Curriculum knowledge, t, c			6.893	
			(4.725)	
Need for PD - Classroom man., t, c				-2.957
				(5.479)
Female, s	18.10***	18.11***	17.70***	18.06***
	(3.181)	(3.184)	(3.219)	(3.168)
Grade, s	33.45***	33.42***	33.49***	33.37***
	(1.644)	(1.634)	(1.626)	(1.629)
Age, s	-5.536	-5.491	-5.340	-5.537
	(3.517)	(3.512)	(3.507)	(3.505)
Highest Schooling Parents ISCED 1, s	10.06*	10.03*	9.579*	10.25*
	(5.542)	(5.544)	(5.568)	(5.564)
Highest Schooling Parents ISCED 2, s	4.816	4.871	4.569	5.001
	(5.695)	(5.677)	(5.687)	(5.692)
Highest Schooling Parents ISCED 3, s	2.814	2.928	2.635	2.959
	(5.461)	(5.426)	(5.447)	(5.478)
Highest Schooling Parents ISCED 4, s	16.69***	16.73***	16.38***	16.79***
	(5.800)	(5.762)	(5.826)	(5.818)
Highest Schooling Parents ISCED 5, s	4.598	4.606	4.371	4.800
	(6.165)	(6.147)	(6.186)	(6.200)
Highest Schooling Parents ISCED 6, s	17.94***	17.97***	17.57***	18.06***
	(5.612)	(5.589)	(5.592)	(5.625)
Social Economic Status Index, s	0.869***	0.870***	0.870***	0.868***
	(0.0627)	(0.0623)	(0.0631)	(0.0626)
Teacher Age Group, t, c	-1.036	-0.916	-0.977	-1.163
	(7.458)	(7.361)	(7.385)	(7.429)
Teacher Education, t, c	-0.438	-0.346	0.535	-0.156
	(7.346)	(7.231)	(7.025)	(7.402)
Teacher Experience, t, c	1.339*	1.355*	1.376*	1.347*
	(0.741)	(0.731)	(0.743)	(0.731)
Class size, t, c	1.005***	1.032***	1.057***	1.006***
	(0.364)	(0.358)	(0.362)	(0.369)
Public School, s	-8.805	-8.677	-8.837	-8.727
	(11.43)	(11.64)	(11.34)	(11.61)
School Size, s	-0.00267	-0.00275	-0.00298	-0.00236
	(0.00265)	(0.00257)	(0.00254)	(0.00269)
Large Village, s	27.40***	27.33***	27.10***	27.29***
	(7.077)	(7.028)	(6.998)	(7.181)
Observations	21,673	21,673	21,673	21,673
R-squared	0.310	0.310	0.311	0.310

In table 6, the regression of the four Need for PD factors on student reading performance are shown. With regards to the subject knowledge variable, no significant effect is found. The reason could be that every teacher already has basic subject knowledge. This basic level of knowledge could already be of significant importance in explaining the subject, regardless of the fact whether the teacher thinks he or she needs more knowledge about this subject. Every additional knowledge on top of this basic level of knowledge might not have any significant marginal gains for the student. Especially, when assuming that reading does not require complex forms of explanation. Practicing reading might be more important than a teacher who knows a lot about the language. The main problems of reading could be that bad reading is a result of a low vocabulary, which is generally gained by practicing reading. Meaning that reading performance might have been influenced more heavily by the characteristics of the students than it is influenced by the subject knowledge of the teacher or the teacher in general, which was also shown in the literature review. In the results, a lower coefficient of teacher experience compared to the other subjects might also be an indication that teachers do not influence student reading performance that much.

The same reasoning goes for pedagogy. A teacher knowing how to explain reading to a child might not be very important. Student reading performance might rely more heavily on student practice than teacher subject knowledge. Therefore, the characteristics of a student has more effect on student reading performance than teacher quality has on student reading performance. This could also be a reason why no significant effect is found

As stated in the data section, four questions about the need for professional development are the components of the Need for PD scale. The two questions that has not been discussed so far are: Need for Professional Development in Curriculum Knowledge and Professional Development in Classroom Management. No significant effect was found for both of these questions, again, suggesting that student reading performance is more heavily influenced by student characteristics than it is by teacher quality.

Mathematics – Need for Professional Development

Table 7 Mathematics - Need for Professional Development

VARIABLES	Math	Math	Math	Math
Need for PD – Subject Knowledge, t, c	-10.14**			
	(4.000)			
Need for PD - Pedagogy, t, c		-7.436		
		(4.942)		
Need for PD - Curriculum knowledge, t, c			-4.038	
			(4.026)	
Need for PD - Classroom man., t, c				-11.78***
				(3.842)
Female, s	-13.95***	-13.73***	-13.34***	-13.88***
	(3.027)	(3.093)	(3.038)	(2.993)
Grade, s	30.27***	30.18***	30.06***	29.92***
	(2.203)	(2.217)	(2.216)	(2.222)
Age, s	-1.377	-1.203	-1.186	-1.643
	(3.890)	(3.962)	(3.922)	(3.843)
Highest Schooling Parents ISCED 1, s	7.069	7.915	7.530	7.068
	(7.265)	(7.482)	(7.461)	(7.195)
Highest Schooling Parents ISCED 2, s	-3.102	-1.813	-1.999	-2.861
	(7.972)	(8.540)	(8.459)	(8.005)
Highest Schooling Parents ISCED 3, s	-0.797	0.454	0.412	-0.0437
	(8.639)	(9.198)	(9.111)	(8.683)
Highest Schooling Parents ISCED 4, s	11.49	12.31	12.40	11.62
	(7.567)	(7.883)	(7.779)	(7.580)
Highest Schooling Parents ISCED 5, s	0.613	1.835	1.637	1.553
	(7.790)	(8.393)	(8.324)	(7.848)
Highest Schooling Parents ISCED 6, s	16.83*	18.06*	18.09**	17.34**
	(8.615)	(9.244)	(9.132)	(8.672)
Social Economic Status Index, s	0.759***	0.761***	0.764***	0.761***
	(0.0685)	(0.0686)	(0.0685)	(0.0689)
Teacher Age Group, t, c	2.270	3.819	3.180	2.111
	(5.727)	(6.037)	(5.955)	(5.548)
Teacher Education, t, c	-1.841	-1.129	-1.443	-1.594
	(5.819)	(5.889)	(5.806)	(5.723)
Teacher Experience, t, c	1.682***	1.583***	1.686***	1.663***
	(0.579)	(0.572)	(0.572)	(0.568)
Class size, t, c	1.067***	1.071***	1.048***	1.069***
	(0.292)	(0.290)	(0.302)	(0.308)
Public School, s	-22.05**	-22.44**	-21.60**	-21.01***
	(8.788)	(8.882)	(8.947)	(8.094)
School Size, s	-0.00411	-0.00355	-0.00367	-0.00402
	(0.00312)	(0.00305)	(0.00309)	(0.00306)
Large Village, s	21.80***	21.35***	21.90***	20.05***
	(6.714)	(6.861)	(6.776)	(6.535)
Observations	20,531	20,531	20,531	20,531
R-squared	0.359	0.358	0.356	0.362
Standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1			

In table 7, the regression of the four Need for PD factors on student mathematics performance are shown. With regards to mathematics a significant negative effect was found for Need for PD in Subject Knowledge. When a teacher feels that he or she needs professional development in this area, students score 10 points fewer for every level of need for PD compared to teachers who stated that they do not need professional development training. Lack of subject knowledge in maths might be the cause of teachers not being able to sufficiently explain complex theorems to students. This could lead to students performing worse in mathematics, as has been shown in the regression.

For pedagogy no significant effects are found. Since the more complex nature of mathematics, it was expected that significant effects were, also, found for this variable. A reason could be that student mathematics performance is more heavily influenced by the subject knowledge of teachers than the pedagogical knowledge of teachers.

With regards to the other two questions: Need for PD on Curriculum Knowledge and Classroom Management, only a significant effect was found for Classroom Management. For every level of Need of Professional Development, students tend to score nearly 12 points fewer. This result suggest that students, participating in mathematics classes with teachers who can maintain discipline and order, perform better than students who are participating in more noisy and less disciplined classrooms.

Science – Need for Professional Development

Table 8 Science - Need for Professional Development

VARIABLES	Science	Science	Science	Science
Need for PD – Subject Knowledge, t, c	-1.228			
	(4.899)			
Need for PD - Pedagogy, t, c		-0.396		
		(4.936)		
Need for PD - Curriculum knowledge, t, c			-7.205	
			(4.843)	
Need for PD - Classroom man., t, c				-4.657
				(4.813)
Female, s	-3.566	-3.560	-3.700	-3.589
	(2.937)	(2.945)	(2.853)	(2.926)
Grade, s	30.90***	30.89***	30.96***	30.86***
	(1.864)	(1.854)	(1.855)	(1.850)
Age, s	-4.620	-4.637	-4.484	-4.414
	(3.624)	(3.628)	(3.632)	(3.623)
Highest Schooling Parents ISCED 1, s	6.561	6.536	6.704	6.853
	(7.778)	(7.798)	(7.719)	(7.764)
Highest Schooling Parents ISCED 2, s	-0.470	-0.486	-0.368	-0.126
	(8.429)	(8.427)	(8.331)	(8.421)
Highest Schooling Parents ISCED 3, s	6.279	6.287	6.178	6.582
	(8.680)	(8.703)	(8.548)	(8.632)
Highest Schooling Parents ISCED 4, s	11.37	11.36	11.46	11.76
	(7.549)	(7.573)	(7.447)	(7.554)
Highest Schooling Parents ISCED 5, s	-0.176	-0.193	-0.0393	0.229
	(9.362)	(9.366)	(9.278)	(9.346)
Highest Schooling Parents ISCED 6, s	18.27**	18.24**	18.42**	18.52**
	(9.056)	(9.077)	(8.980)	(9.045)
Social Economic Status Index, s	0.774***	0.774***	0.769***	0.771***
	(0.0610)	(0.0606)	(0.0595)	(0.0602)
Teacher Age Group, t, c	-3.002	-2.980	-3.185	-2.854
	(5.959)	(5.928)	(5.959)	(5.948)
Teacher Education, t, c	17.04***	17.16***	16.61***	17.37***
	(6.137)	(6.091)	(5.975)	(6.027)
Teacher Experience, t, c	1.649***	1.651***	1.651***	1.580***
	(0.578)	(0.580)	(0.586)	(0.576)
Class size, t, c	0.701**	0.697**	0.721**	0.701**
	(0.290)	(0.293)	(0.291)	(0.293)
Public School, s	-17.70**	-17.73**	-17.38**	-17.80**
	(8.389)	(8.365)	(8.504)	(8.523)
School Size, s	-0.00446	-0.00444	-0.00475*	-0.00443
	(0.00279)	(0.00280)	(0.00279)	(0.00283)
Large Village, s	20.84***	20.88***	20.91***	21.08***
	(7.174)	(7.134)	(7.232)	(7.248)
Observations	21,363	21,363	21,363	21,363
R-squared	0.305	0.305	0.307	0.306

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

In table 8, the regression of the four Need for PD factors on student science performance are shown. For student science performance, just like reading performance, no significant effect is found to the professional development needed for both subject knowledge and pedagogy. Just like with reading performances, student might be more heavily influenced by student characteristics than by teacher quality. Another reason could be that science teachers might share common characteristics that are not accounted for in this paper.

Control variables – Need for Professional Development

Female students perform better in reading, but are worse in mathematics. However, no significant effect is found for student science performance. Students enrolled in higher grades tend to perform much better than students who are enrolled in lower grades. The difference between the lowest grade (-3) and the highest grade (2) are as much as 150 points. This seems logical because of the generalised structure of the performance test. Smarter students enrolled in higher grades will do better on the test than students who are enrolled in lower grades. Age does not seem to affect student performance. Although older students tend to perform better on tests than younger students, the age gap between 15.25 and 16.33 might be too small to show a significant difference. No consistent significant effects are found with regards to parental education. Only students with a parent who received the highest form of education tend to perform better. The Social Economic Status Index does have a significant effect on student performance. Students performance increases with 0.8 point for every point their social economic status index increased. Meaning that wealthier students tend to perform better than poorer students. The education of the teacher only seems to affect student science performance. Students score 16 point higher when for every ISCED level of the teacher. The experience of the teacher also increases student performance in every subject. However, the effects differ for each subject. Negative effects are found when student are attending a public school with regards to student mathematics and science performance. Intuitively, this follows logical reasoning, since private schools have better teachers and tend to enrol only the brightest students. Living in a city with more than 100,000 inhabitants, also, has a significant, positive effect on student performance.

Need for Professional Development Scale

Table 9 Results of Need for PD - scale on student reading, mathematics and science performance

VARIABLES	Reading	Mathematics	Science
Need for PD - Scale, t, c	0.0799	-4.227***	-0.762
	(2.334)	(1.524)	(2.111)
Female, s	18.07***	-13.78***	-3.575
	(3.201)	(3.064)	(2.933)
Grade, s	33.45***	30.09***	30.91***
	(1.641)	(2.221)	(1.860)
Age, s	-5.523	-1.372	-4.596
	(3.519)	(3.912)	(3.624)
Highest Schooling Parents ISCED 1, s	10.04*	7.538	6.615
	(5.558)	(7.457)	(7.786)
Highest Schooling Parents ISCED 2, s	4.843	-2.498	-0.394
	(5.686)	(8.422)	(8.439)
Highest Schooling Parents ISCED 3, s	2.866	-0.0891	6.326
	(5.457)	(9.053)	(8.663)
Highest Schooling Parents ISCED 4, s	16.71***	11.62	11.44
	(5.823)	(7.785)	(7.548)
Highest Schooling Parents ISCED 5, s	4.598	1.360	-0.101
	(6.192)	(8.260)	(9.363)
Highest Schooling Parents ISCED 6, s	17.95***	17.36*	18.33**
	(5.601)	(9.072)	(9.081)
Social Economic Status Index, s	0.869***	0.760***	0.773***
	(0.0624)	(0.0689)	(0.0606)
Teacher Age Group, t, c	-0.953	3.165	-2.986
	(7.460)	(6.010)	(5.953)
Teacher Education, t, c	-0.442	-1.398	17.11***
	(7.290)	(5.907)	(6.076)
Teacher Experience, t, c	1.345*	1.604***	1.641***
	(0.740)	(0.577)	(0.577)
Class size, t, c	1.018***	1.066***	0.702**
	(0.359)	(0.296)	(0.293)
Public School, s	-8.527	-21.54**	-17.68**
	(11.55)	(8.481)	(8.399)
School Size, s	-0.00270	-0.00415	-0.00447
	(0.00262)	(0.00307)	(0.00279)
Large Village, s	27.38***	21.19***	20.93***
	(7.049)	(6.694)	(7.167)
Observations	21,673	20,531	21,363
R-squared	0.310	0.359	0.305

Reading – Need for Professional Development Scale

As is shown in table 9, Need for PD - Scale does not have significant effect on student reading performance. The conclusion that can be drawn from this output is similar to the conclusion of the previous analysis including the four questions about the need for professional development. Maybe student reading performance is more influenced by the student characteristics than by teacher quality.

Mathematics – Need for Professional Development Scale

Need for PD (scale) has a significant, negative effect on student's mathematics performance. Students score 4.2 points fewer for each value the need for professional development increases. Because the minimum and maximum of the scale is 4.7, respectively 16.1, a student would score a maximum of 47.88 points lower when having a teacher who stated that he or she is in great need of professional development than a teacher who stated that he or she does not need any professional development.

Mathematics students might actually, therefore, benefit from teachers who do not feel the need for professional development. In the previous model significant effects are found for Need for Professional Development in Subject Knowledge and Classroom Managements. Therefore, finding a significant effect when using the scale, which has been rated on what the teacher answered to the four questions, was expected.

Science – Need for Professional Development Scale

Similar to the results for reading performances. Need for professional development does not have a significant effect on student science performance. Similar to the first regression, no strong significant effects on student performance are found in the second regression.

Student science performance tend to be more dependent on student characteristics than it is on teacher quality.

Control variables - Need for Professional Development Scale

Control variables show strong consistency between the first and second regression model, proving that they are good control variables. Whether the four questions on the need for professional development or a scale is used, the control variables show around the same coefficients and significance levels. Because the control variables do not shift too heavily proves that the scale represents the four questions on professional development.

Interaction effects – Need for Professional Development Scale

In Appendix 2 – Interaction tables 14, 15 and 16 the results are shown for the interaction effects between Need for Professional Development Scale and OECD, Teacher Experience, and Public School are shown.

In this study I check whether teachers from rich countries have a different effect on students when they state they need professional development than teachers from poor countries. Maybe teachers in rich countries can make more accurate estimations whether they need professional development due to more feedback moments or other assessment measures of teachers. This might could give teachers in rich countries give more significant estimations and poorer countries less significant estimations. The reason to include teacher experience as an interaction effects is because, teacher experience can influence how well a teacher can assess him or herself whether he or she needs professional development. On the other hand, younger teachers might be more inclined to say that they need professional development simply because they are inexperienced and still need to learn a lot. Experienced teacher might be less inclined to say that they need professional development just because they are experienced. To see the effect on students performance can give interesting insights. The inclusion of Public School as an interaction effects is because of the difference between teachers of public schools and teacher of private schools. Private school teachers might be more inclined to say that they need professional development than teachers from public schools. On the other hand teachers from private schools might receive more professional development in general than public school teachers and therefore feel less need for professional development.

Looking into student reading performance in table 14 no significant different results are seen compared to the original estimation. Only the main effects change when the interaction effect is added to the regression. When the interaction effect with OECD is added, the coefficient of OECD becomes larger than the coefficient of OECD in the original setting. As is shown in the original regression, if assumed that Need for PD – Scale is significant, student reading performance increases when a teacher notes that he or she do have a Need for PD. The same is observed when OECD is added. In case of teacher experience, the coefficient of teacher experience becomes smaller and insignificant. When public school is interacting with Need for PD Scale, the coefficient becomes smaller but remains insignificant. Since the interaction effects did not show a significant effect for Need for PD, suggesting that outcomes do not significantly differ for different groups of teachers.

Student mathematics performances do differ a little when interaction effects are introduced in table 15. OECD students tend to perform better on average compared to non-OECD countries. Need for

PD - Scale becomes insignificant when it is interacting with OECD countries. The coefficient of OECD becomes larger, meaning that students in OECD countries generally perform better in mathematics. If both Need for PD – Scale and the interaction effect are assumed to be significant, the results would suggests that teachers perform worse when they live in a non-OECD country than when they live in a OECD country, for any value on the Need for PD scale.

Next the interaction effect with teacher experience is shown. The coefficient of Need for PD Scale decreases compared to the original setting, meaning that students score worse when teachers note that they need professional development, but the interaction term suggests a positive effect meaning that students would perform better when Need for PD increases in combination with teacher experience. The main effect; teacher experience becomes insignificant. These results suggest that, for a constant level of Need for PD, an increase in teacher experience would results in better student performance, if the coefficient of teacher experience is assumed to be significant. This indicates that younger teachers perform worse than more experienced teacher for the same level of Need for PD. The reason could be that more experienced teachers might feel that they could benefit from PD, but because of their experience they are still able to teach students better than their inexperienced colleagues.

On major sidenote to this regression is the following: if teachers with 25 years of experience and a low level of need are compared to teachers with 25 years of experience and a high level of need, it is shown that students perform better with a teacher with a high level of need. This is also the case for teachers that have more than 25 years of experience. All the teachers below this threshold perform worse when Need for PD – Scale increases, which is logical. The reason for this interesting phenomenon could be the subjective nature of the Need for PD – Scale variable. Maybe younger teachers might note that they need PD more heavily, because they are not experienced. Because of their inexperience, they would suggest that they need professional development. On top of that, their inexperience results in worse student performance. This would result in a decrease in student performance when need for PD increases.

Why experienced teachers perform better when Need for PD increases is not logical and should be studied more in-depth. Maybe experienced teachers think they do not need professional development because of their experience, but in reality they are performing badly. This could result in experienced teachers who stated that they have a low level of need for PD perform worse than experienced teacher that stated a high level of need for PD.

Next is interaction effect with public school, it shown that the coefficient of Need for PD – Scale decreases compared to the original regression. A sharp decline in the coefficient of Public School is

also observed. On top of that, a positive interaction effect is observed, although this effect is insignificant. Assuming that it is significant. These results suggest that for every level of Need for PD below Public School will always be performing worse than private schools. Above this threshold, teachers are performing similarly. Teachers who noted a low level of need are generally better in private schools than in public schools, however this effect is diminishing, when Need of PD is increasing. Meaning that teachers in private schools react more heavily to an increase in Need for PD than teachers in private schools. Therefore it can be suggested that teachers with a high level of need for PD are performing equally bad in public school as in private schools, in contrast to the original regression that suggested that public schools always performed worse, regardless of the level of need for PD.

In table 16 no significant differences are observed between student science performance and the interaction effects, teacher experience and public school. This suggests that there are no systematic differences across these groups of teachers. Only when Need for PD – Scale interacts with OECD, the main effects and interaction effect are significant. An interesting phenomenon shows that in non-OECD countries student performance increases when Need for PD – Scale also increases, whereas in OECD countries student performance decreases when Need for PD – Scale increases. Another finding is, that when Need for PD is higher than 9 students in OECD countries perform worse than students in non-OECD countries. Similarly to what has been discussed in the student mathematics performance part, this could be a result of the subjective nature of this variable. Further research on this phenomenon might give an explanation to this.

Received Professional Development

In the previous two regressions, teacher's self-reported need for professional development was used as the independent variable. In table 10 below, the variable that states whether the teacher has received professional development training in the last 12 months is used. This variable is not prone to subjective answers like independent variables in the previous two regressions. The teachers simply took or did not take professional development training.

Table 10 Results of teachers that received PD on student performance

VARIABLES	Reading	Mathematics	Science
Received Professional Development, t, c	27.17*	12.81	20.26
	(14.22)	(13.50)	(12.82)
Female, s	18.43***	-13.28***	-4.179
	(3.088)	(3.032)	(2.769)
Grade, s	33.13***	30.00***	30.40***
	(1.628)	(2.205)	(1.816)
Age, s	-5.611	-0.961	-4.194
	(3.488)	(3.935)	(3.718)
Highest Schooling Parents ISCED 1, s	10.38*	7.461	6.531
	(5.542)	(7.434)	(7.680)
Highest Schooling Parents ISCED 2, s	5.073	-2.043	-0.485
	(5.731)	(8.455)	(8.283)
Highest Schooling Parents ISCED 3, s	3.294	0.134	6.270
	(5.445)	(9.106)	(8.506)
Highest Schooling Parents ISCED 4, s	16.94***	12.30	11.29
	(5.746)	(7.810)	(7.465)
Highest Schooling Parents ISCED 5, s	5.374	1.589	0.537
	(6.008)	(8.307)	(9.245)
Highest Schooling Parents ISCED 6, s	18.11***	18.15**	18.19**
	(5.531)	(9.100)	(8.927)
Social Economic Status Index, s	0.862***	0.763***	0.773***
	(0.0640)	(0.0688)	(0.0616)
Teacher Age Group, t, c	-0.424	4.550	-2.553
	(7.094)	(6.019)	(5.545)
Teacher Education, t, c	-0.428	-1.445	16.62***
	(7.267)	(5.924)	(6.149)
Teacher Experience, t, c	1.349*	1.584***	1.631***
	(0.724)	(0.579)	(0.576)
Class size, t, c	0.998***	1.001***	0.607**
	(0.353)	(0.303)	(0.291)
Public School, s	-8.565	-22.15**	-19.92***
	(10.53)	(9.304)	(7.340)
School Size, s	-0.00334	-0.00317	-0.00389
	(0.00255)	(0.00314)	(0.00277)
Large Village, s	26.84***	22.09***	19.26***
	(6.674)	(6.828)	(6.779)
Observations	21,673	20,531	21,363
R-squared	0.313	0.356	0.308

Reading – Received Professional Development

A small ($p<0.1$) significant effect is found for received professional development. Students whose teachers who took professional development education tend to score 27.2 points better on their reading performance tests. This small p-value means the coefficient is not very significant but it can give a good indication that Professional Development is a good tool to improve teacher quality and student performance.

In the previous two regressions the possible reason why the need for professional development did not have a significant effect on student performance was that student performance is more heavily influenced by student characteristics rather than teacher quality. Observing teachers who received professional development have a significant effect on student reading performance suggests something different. The reason for this difference is that the questions of need for professional development are bound to very subjective answers, especially when a Likert scale is used. Teachers might wrongly estimate their need for professional development. With regards to Received Professional Development, teachers cannot give subjective answers. They either participated in professional development or simply did not. The different nature of answering Need for Professional Development questions and participating in professional development could, therefore, lead to different results.

Mathematics – Received Professional Development

Teachers who received professional development do not have a significant effect on student mathematics performance. This was not expected, because in the previous estimation a significant effect was found when teacher answered that they would need professional development. Why a different results is found might be in the nature of the subject. Mathematics teachers might benefit from various other professional development activities than reading teachers do. Some professional development activities might have an effect on the teacher quality and therefore student performance, whereas some professional development activities do not. The question on whether or not the teacher participated in professional development activities does not elaborate on the kinds of professional development activities. This could lead to the combination of professional development activities each with a different effectiveness on mathematics teachers. A combination of effective and ineffective professional development activities could lead to an insignificant effect on student mathematics performance.

The reason why a significant effect is found for reading could be that more kinds of professional development activities lead to increased teacher quality and student performance.

Science – Received Professional Development

For student science performance, no significant effect is found. Just like in the previous two regressions no significant effects were found in this regression as well. Students were not being penalized by teachers who needed professional development. Therefore, it is not surprising to see that teachers who received professional development did not have a significant effect on student science performance. As has been suggested in the previous subsection, student science performance might rely more on student characteristics than it relies on teacher quality.

Another reason why no (strong) significant effects are found in this regression model is that teachers who received professional development training were already performing poorly in the first place. Since the teacher was already doing poorly before professional development training, the students performances might have improved too little or not at all. This self-selection bias leads to an underestimation of the training and, therefore, to non-significant results.

Control variables – Received Professional Development

The control variables do not change significantly when the regression changed from the need for professional development to Received Professional Development, again, suggesting that good control variables are used in this paper.

Interaction effects – Received Professional Development

The results in the previous subsection suggest that the effects found are representable to the entire sample of teachers. However, when teachers take professional development training the effect can differ across specific groups of teachers. Professional development training might differ across rich and poor countries. Teachers might have better professional development classes in richer countries, because these teachers might have more individual budget to get better courses. Richer countries might be able to provide better professional development training than poorer countries, just because schools in richer countries might have more resources in general than schools in poorer countries. . The results might also differ when these teachers just started teaching opposed to teachers who have practiced the profession for a long time. Less experienced teacher might benefit more from professional development, because they know not as much as more experienced teachers. More experienced teachers could be more rusty and stick to what they already know, because they have been practicing the job for years. These reasons might lead to different outcomes in student performances between less experienced teachers and more experienced teachers. Professional development training taken by private school teachers might have a different effect on student performance than public school teachers have, because teachers from a private schools might be able to participate in better professional development training than their public school colleagues.

In table 11, 12 and 13, the regressions are shown. In the first column, the basic regression was run. The second column shows the interaction effect of the independent variable on a rich country. The third column shows the interaction effects with teacher experience and the last column shows the interaction effect with Public School. Only the main effects and interaction effect are shown, because coefficients and significance levels of the control variables did not change significantly and are therefore not shown in these tables.

Table 11 Reading - Received PD - Interaction effects

VARIABLES	Original	OECD	Teacher Experience	Public School
Received Professional Development, t, c	27.17*	10.92	62.26*	103.9**
	(14.22)	(12.52)	(32.86)	(52.61)
Received Professional Development * OECD		16.60		
		(21.00)		
Received Professional Development * Teacher Experience			-1.917	
			(1.425)	
Received Professional Development * Public School				-90.20
				(56.76)
OECD	27.09**	11.83	26.07***	25.61***
	(8.005)	(21.30)	(8.555)	(7.931)
Teacher Experience, t, c	1.349*	1.349*	3.009**	1.274*
	(0.724)	(0.724)	(1.407)	(0.723)
Public School, s	-8.565	-8.577	-10.51	72.70
	(10.53)	(10.51)	(9.832)	(54.14)
Observations	21,673	21,673	21,673	21,673
R-squared	0.313	0.313	0.315	0.318

For reading, using an interaction effect with OECD and Received Professional Development resulted in no significant effect for the main effects: OECD and Received Professional Development, and the interaction effect. This outcome suggests that there are no significant differences between taking professional development training in a rich country and a poor country. This was not expected since OECD countries should have better institutions that provide better professional development training. It might still be the case that these countries are able to provide better training, but it is not significantly reflected on student performance.

When looking into the interaction effect with teacher experience, an interesting effect is observed. The coefficient of both Received Professional Development and Teacher Experience have become larger, on top of that Teacher Experience has become more significant with a p-value smaller than 0.05. The interaction effect is not significant but it has a negative coefficient. Although the interaction effect is not significant, these results would suggest that less experienced teachers would benefit more from professional development than more experienced teachers do. If assumed that

the interaction effect is significant, the effectiveness of professional development training decreases when the experience increases. Even to the extent, that when teachers reach 32 years of experience, they would start having a negative effect on student performance compared to when they would not have received professional training. To further examine this effect, another regression was run with dummy variables for every 5 years of teachers experience, which is shown Appendix 2 – Interaction Tables – Received Professional Development in table 17. In here, it can be observed that the coefficient has slightly decreased compared to the regression without the dummy variables. In this regression, it is also shown that no significant effects are shown for the first 30 years of experience, but for teachers with more than 30 years of experience significant negative effects are found that are outweighing the main effect of having received professional development training. Similar to what was shown in table 11, this table suggests that professional development might be more beneficial for new teachers than it is for more experienced teachers. This seems logical, since starting teachers are new to the job and need to get used to standing in front of a classroom. Professional development training would help them getting started. New teachers might be participating in trainings because they know they are inexperienced. They also might be more open to implement new ideas in their classroom than more experienced teachers. On the other hand, more experienced teachers might find it harder to implement new ideas, since they have been in this profession for a long time already. On top of that, more experienced teachers who were performing badly already, were probably still performing badly after they have received professional development and experienced teachers who were performing well, did not feel the need for professional development in the first place. This would lead to a self-selection bias in which good teachers would not take professional development training and bad teachers would have taken the training. This bias results in an underestimation of the effect that professional development training has on student performance and a negative effect when it comes to older, more experienced teachers. This might explain why more experienced teachers are performing worse when they participated in professional development classes.

When it comes to the difference between public and private schools, coefficients vastly differ from the original regression. Only the significance level of Received Professional Development increases, due to a p-value that is smaller than 0.05. Further Public School and the interaction effect are not significant. This means that there is no significant difference between professional development training taken by teachers from a public school and a private school.

Assuming that they are significant, the results show that teachers from private schools benefit more from professional development training than teachers from public schools do. But the results also suggest that when a private school and a public school both did not participate in professional

development training, the public school would perform 72 points better than the private school. Only if 80 percent of the teachers in a private school took professional development classes, teachers from private schools would outperform teachers from a public schools.

Table 12 Mathematics - Received PD - Interaction effects

VARIABLES	Original	OECD	Teacher Experience	Public School
Received Professional Development, t, c	12.81	16.57	27.45	19.56
	(13.50)	(17.98)	(29.33)	(38.66)
Received Professional Development * OECD		-3.837		
		(22.56)		
Received Professional Development * Teacher Experience			-1.030	
			(1.597)	
Received Professional Development * Public School				-8.629
				(39.03)
OECD	39.30***	42.45*	39.89***	39.23***
	(10.68)	(22.73)	(10.35)	(10.71)
Teacher Experience, t, c	1.584***	1.584***	2.550	1.604***
	(0.579)	(0.580)	(1.610)	(0.577)
Public School, s	-22.15**	-22.16**	-22.58**	-14.44
	(9.304)	(9.301)	(9.322)	(36.61)
Observations	20,531	20,531	20,531	20,531
R-squared	0.356	0.356	0.357	0.357

Regarding student mathematics performance, Received Professional Development remains insignificant in every interaction effects regression, as is shown in table 12. These result were expected, since in the original regression Received Professional Development does not have a significant effect on student performance as well. Students in OECD countries are generally performing better, hence the OECD variable is significant. It is surprising to see that professional development training taken in an OECD country, has a negative effect on student performance. It is not significant, but might give an indication.

Table 13 Science - Received PD - Interaction effects

VARIABLES	Original	OECD	Teacher Experience	Public School
Received Professional Development, t, c	20.26	19.67	42.55*	46.39*
	(12.82)	(18.05)	(22.58)	(23.71)
Received Professional Development * OECD		0.597		
		(22.45)		
Received Professional Development * Teacher Experience			-1.580	
			(1.148)	
Received Professional Development * Public School				-37.61
				(27.17)
OECD	6.422	5.903	7.171	8.907
	(12.53)	(22.32	(12.29)	(11.96)
Teacher Experience, t, c	1.631***	1.631***	2.982***	1.634***
	(0.576)	(0.576)	(1.075)	(0.583)
Public School, s	-19.92***	-19.92***	-21.80***	10.67
	(7.340)	(7.354)	(7.358)	(24.38)
Observations	21,363	21,363	21,363	21,363
R-squared	0.308	0.308	0.310	0.310

When it comes to Science, table 13 shows interesting changes in the interaction effects model. Similarly to reading performances, when an interaction effect with teacher experience is included, Received Professional Development becomes significant on a low level ($p<0.1$). An increase in the coefficient of Received Professional Development and Teacher experience and a negative coefficient for the interaction term suggest that less experienced teachers benefit more from professional development training than experienced teachers. To further examine this, again, another regression was run with dummy variables for every 5 years of teachers experience, that is shown in Appendix 2 – Interaction Tables – Received Professional Development in table 18. This regression, however, is not similar to the reading performance regression. Received Professional Development, namely, is not significant. On the other hand, a similar pattern is shown that student performance decreased when more experienced teachers took professional development training. This could be a results of the self-selection bias, as has been previously discussed in the reading regression.

Furthermore, similarities with the reading regression are shown when an interaction effect is constructed between Professional Development and Public School. Again assuming that the effects are significant, private school teachers who participated in professional development training are performing better than public school teachers who participated in professional development training. However, this regression also suggests that when neither private school teachers nor public school teachers participated in any professional development training, students enrolled in public schools tend to perform better. Only when the fraction of teachers that took professional

development training is above 20%, students in private schools perform better than students in public schools. Although these effects are not significant, these indications are still deviant from what would be intuitively expected.

6. Conclusion and Limitations

Conclusion

In this paper, the effect of teacher's subject knowledge and pedagogy skills on student performance has been studied. Previous studies have shown that finding consistent, significant effects school resources and teacher quality on student outcomes is very difficult. Student background has always been a predominant factor influencing student performance, rather than teacher or school characteristics. Recent years, multiple studies have shown a slight increasing trend, proving that teachers have a bigger influence on student performance than has previously been thought. Therefore, a new study by combining two extensive datasets provided an unique opportunity to study these effects. These datasets included a large sample containing students, teachers and schools from all over the world, and, therefore, gave interesting insights whether the improvement of teacher quality increases student performance. By running three separate OLS regression for each subject, the effect of professional development on student performance has been estimated. The results carefully suggest that professional development can be a useful tool to improve teacher quality and student performance, especially for less experienced teachers. Although, no consistent findings are found between subjects and even between different regression analyses, this study has offered interesting insight in the determinants of student performance.

As has been stated in the literature, observing teachers and quantifying their classroom practices has proven to be difficult. In this study, the quantification of several aspects of professional development led to an increase in sample size, but also to inaccurate use of measurements of professional development. To improve this study, it would be interesting to look into the different kinds of professional development activities that prove effective in improving teacher quality. Moreover, the time spend on professional development might also be important. This can lead to more consistent findings across subjects.

Therefore, future studies could focus more on this kind of in-depth research. Quantifying, accurate professional development activities and teacher practices is very difficult and collecting this data is very labour intensive and, thus, very expensive. This is might not be feasible in countries that already face more difficulty in providing good education, and, therefore, do not have the means to carry out such data collection.

Limitations

A limitation to this research is that this study only studies students and teacher in 2018. Sanders and Rivers (1996) show that students who are assigned consecutive ineffective teachers perform worse than students are assigned more capable teachers in a row. Teacher characteristic effects tend to be cumulative. This is a major limitation to this study, since students could be affected by teachers they were assigned to the years before this study was conducted. An improvement would be that students and his or her teachers are studied longitudinally over several years.

The fact that I was not able to link the exact students to their teachers is another limitation. In this study I partly resolve this issue by averaging the values of teachers characteristics. This, however, leads to inaccurate calculations of the effect teacher quality has on student performance. This problem can be resolved when teachers are linked to their students participating in their classes, to truly observe the individual characteristics of the teacher on his or her students.

The self-selection bias is also a major limitation in this study. Self-selection leads to teachers that perform badly would join professional development training more often than teachers that were already performing well. As explained before, teachers who would perform badly before professional development training, might still badly after the training. To resolve this issue, it would be useful to look at teachers for a longer period of time, namely before and after professional development training.

Another limitation is that the variables of interest are self-reported. This results in that teachers, whose students are performing badly in classes, already feel or have an indication that their subject knowledge or pedagogy skills are not sufficient. This endogeneity problem can be solved via external observation of a neutral institution. This person could be a delegate from the ministry of education, or maybe someone who works for PISA. This external observation could give better unbiased observation whether a teacher is performing well or badly. However, similar to the improvement mentioned in the conclusion, this would be a costly way to measure teacher performance. In turn, this would result in a smaller sample size.

Another problem with the self-reported questionnaire is that participants tend to fill in socially desirable answers. Teachers might experience social pressure to give more desirable answer, either to comfort themselves or others. Or they either overestimate their true ability of teaching. This could lead to an underestimation of the results, since the true value of the need for professional development might be higher in reality than is found in the data. An external observation could resolve this issue and therefore leading to more reliable data and results.

7. Bibliography

Begle, E. G., & Geeslin, W. (1972). Teacher effectiveness in mathematics instruction. *National Longitudinal Study of Mathematical Abilities Reports No. 28.*, Washington D.C. Mathematical Association of America and National Council of Teachers of Mathematics.

Bielefeldt, T. (2005). Computers and student learnings: Interpreting the multivariate analysis of PISA 2000. . *Journal of Research on Technology in Education, 37(4)*, 339-347.

Bowen, H. (2018). *Investment in learning: The individual and social value of American higher education.* Jossey-Bass Publishers.

Brookover, W. B., & Lezotte, L. W. (1979). C. *Changes in School Characteristics Coincident With Changes in Student Achievement. Occasional Paper No. 17.*

Byrne, C. J. (1983). Teacher knowledge and teacher effectiveness: A literature review, theoretical analysis and discussion on research strategy. Ellenville, New York: Paper presented at the meeting of the Northwestern Educational Research Association.

Cohen, D., & Hill, H. C. (1992). Intructional Policy and Classroom Performance: The Mathematics Reform in California. *Consortium for Policy Research in Education, Philadelphia*.

Coleman , J. S., Campbell, E. Q., Hobson, C. J., McPartland, J., Mood, A. M., Weinfeld, F. D., & York , R. L. (1966). *Equality of educational opportunity.* Washington D.C.: U.S. Government Printing Office.

Darling-Hammond, L. (2000). Teacher quality and student achievement. *Education policy analysis archives, 8, 1*.

Darling-Hammond, L., & Richardson , N. (2009). Research review/teacher learning: What matters. *Educational leadership 66(5)*, 46-53.

Delprato, M., & Chudgar, A. (2018). Factors associated with private-public school performance: Analysis of TALIS-PISA link data. *International Journal of Educational Development, 61*, 155-172.

Dincer, M. A., & Uysal, G. (2010). The determinants of student achievement in Turkey. *International Journal of Educational Development 30(6)*, 592-598.

Dogan, S., & Yurtseven, N. (2018). Professional learning as a predictor for instructional quality: a secondary analysis of TALIS. *School Effectiveness and School Improvement, 29(1)*, 64-90.

Doherty, R. W., & Hilberg, R. S. (2007). Doherty, R. W., & Hilberg, R. S. (2007). Standards for effective pedagogy, classroom organization, English proficiency, and student achievement. *The Journal of Educational Research, 101(1)*, 24-35.

Edmonds, R. (1979). Effective schools for the urban poor. *Educational Leadership 37(1)*, 15-24.

Fenstermacher, G., & Richardson, V. (2005). On making determinations of quality in teaching. *Teachers college record 107(1)*, 186-213.

Ferguson, R. F. (1991). Paying for public education: New evidence on how and why money matters. *Harvard Journal on Legislation 28(457)*, 465-498.

Ferguson, R. F., & Ladd, H. F. (1996). How and why money matters: An analyses of Alabama schools. *Holding schools accountable: Performance-based reform in education 265*, 298.

Frome, P., Lasater , B., & Cooney, S. (2005). Well-Qualified Teachers and High Quality Teaching: Are They the Same? *Southern Regional Education Board, Research Brief*.

Gerritsen, S., Plug, E., & Webbink, D. (2017). Teacher quality and student achievement: evidence from a sample of dutch twins. *Journal of Applied Econometrics 32(3)*, 643-660.

Goe, L. (2007). The Link Between Teacher Quality and student outcomes: A research synthesis. *National comprehensive center for teacher quality*.

Goldhaber, D. D., & Brewer, D. J. (1996). Why don't schools and teachers seem to matter? Assessing the impact of unobservables on educational productivity. *Journal of Human Resources 32(2)*, 505-520 .

Govorova, E., Benitez, I., & Muniz, J. (2020). Predicting Student Well-Being: Network Analysis Based on PISA 2018. *International Journal of Environmental Research and Public Health 17(11)*, 4014.

Hanushek, E. A. (1997). Assessing the effects of school resources on student performance: An update. *Educational evaluation and policy analysis, 19(2)*, 141-164.

Hanushek, E. A., & Kimko, D. D. (2000). Schooling, labour-force quality, and the growth of nations. . *American Economic Review 90(5)*, 1184-1208.

Hanushek, E. A., Kain, J. F., O'Brien, D. M., & Rivkin, S. G. (2005). The Market for Teacher Quality: NBER Working Paper No. 11154. *National Bureau of Economic Research.*

Hawk, P., Coble, C. R., & Swanson, M. (1985). Certification: It Does Matter. *Journal of Education 36(3)*, 13-15.

Heneman III, H. G., Milanowski, A., Kimball, S., & Odden, A. (2006). Standards-based teacher evaluation as a foundation for knowledge- and skill-based pay. *CPRE Policy Briefs*.

Huang, J., Tang, Y., He, W., & Li, Q. (2019). Singapore's School Excellence Model and student learning: evidence from PISA 2012 and TALIS 2013. *Asia Pacific Journal of Education 39(1)*, 96-112.

Kannapel, P. J., Clements, S. K., Taylor, D., & Hibpshman, T. (2005). Inside the black box of high-performing high-poverty schools. *Report, Prichard Committee of Academic Excellence*.

Kasalak, G., & Dagyar, M. (2020). The Relationship between Teacher Self-Efficacy and Teacher Job Satisfaction: A Meta-Analysis of the Teaching and Learning International Survey (TALIS). *Educational Sciences: Theory and Practice, 20(3)*, 16-33.

Lee, V. E., Bryk, A. S., & Smith , J. B. (1993). Chapter 5: The organization of effective secondary schools. *Review of research in education 19(1)*, 171-267.

Lopes, J. A., & Oliviera, C. (2021). Teacher and school determinants of perceived classroom discipline: a multilevel analysis of TALIS 2013. . *Learning Environments Research*, 1-18.

Macdonald, K. (2019). "PV: Stata module to perform estimation with plausible values,". *Boston College Department of Economics*, Statistical Software Components S456951.

Marcoulides, G. A., Heck, R. H., & Constantinos, P. (2005). Student perceptions of school culture and achievement: testing the invariance model. *International Journal of Educational Management*.

Marzano, R. (2003). What works in schools: translating research into action. *Association for Supervision and Curriculum Development*, Alexandria, VA.

Metzler, J., & Woessmann, L. (2012). The impact of teacher subject knowledge on student achievement: Evidence from within-teacher within-student variation. *Journal of Development Economics 99(2)*, 486-496.

Monk, D. H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review 13(2)*, 125-145.

National Center for Education Statistics. (1994). Data compendium for the NAEP 1992 reading assessment of the nation and the states: 1992 NAEP trial state assessment. Washington, D.C: U.S. Department of Education.

OECD . (2009). PISA Data Analysis Manual: SAS, Second Edition, PISA. *OECD Publishing, Paris*.

Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research 81(3)*, 376-407.

Perry, L., & McConney, A. (2010). Does the SES of the school matter? An examination of socioeconomic status and student achievement using PISA 2003. *Teachers College Record 112(4)*, 1137-1162.

Sanders, W. L., & Rivers, J. C. (1996). Cumulative and residual effects of teachers on future student academic achievement. *University of Tennessee Value-Added Research and Assessment Center* .

Schacter, J., & Thum, Y. M. (2004). Paying for high- and low-quality teaching. *Economics of Education Review 23(4)*, 411-430.

Telese, J. A. (2012). Middle School Mathematics Teachers' Professional Development and Student Achievement. *The Journal of Educational Research 105(2*, 102-111.

Wallace, M. R. (2009). Making sense of the link: Professional development, teacher practices, and student achievement. *Teachers College Record, 111(2)*, 573-596.

Wenglinsky, H. (2002). The link between teacher classroom practices and student academic performance. *Education policy analysis archives (10)*.

Wiley , D., & Yoon, B. (1995). Teacher reports of opportunity to learn: Analyses of the 1993 California Learning Assessment System. *Educational Evaluation and Policy Analyses 17(3)*, 355-370.

Woessman, L. (2001). New Evidence on the Missing Resource-Perfomance Link in Education. *Kiel Woeking Paper (1051)*.

8. Appendix

Appendix 1

Variable	Obs	Mean	Std. Dev.	Min	Max
PV1READ	25,148	462.8309	101.6821	120.243	837.275
PV2READ	25,148	463.7106	102.0845	79.481	835.759
PV3READ	25,148	462.7737	101.8408	145.823	850.737
PV4READ	25,148	463.2496	101.7546	134.196	813.593
PV5READ	25,148	463.193	101.5991	83.661	785.869
PV6READ	25,148	463.4348	101.7579	48.433	798.388
PV7READ	25,148	463.1183	101.349	120.441	822.127
PV8READ	25,148	462.9866	101.6066	124.007	807.799
PV9READ	25,148	462.8779	101.7669	116.813	831.732
PV10READ	25,148	462.9571	101.5551	112.938	835.237

Variable	Obs	Mean	Std. Dev.	Min	Max
PV1MATH	24,017	458.9542	99.05581	120.973	816.064
PV2MATH	24,017	458.8615	98.39927	117.131	815.645
PV3MATH	24,017	458.8204	99.10519	91.638	814.033
PV4MATH	24,017	459.1727	99.49988	96.439	817.901
PV5MATH	24,017	459.6857	99.50037	117.644	844.204
PV6MATH	24,017	459.784	98.53263	5.215	810.438
PV7MATH	24,017	459.5381	98.68077	117.331	811.663
PV8MATH	24,017	459.012	98.65397	112.967	806.78
PV9MATH	24,017	458.7317	99.33063	102.98	872.412
PV10MATH	24,017	458.4664	99.15894	134.544	817.914

Variable	Obs	Mean	Std. Dev.	Min	Max
PV1SCIE	24,724	466.51	98.70759	122.363	827.421
PV2SCIE	24,724	465.7674	98.94601	147.756	827.404
PV3SCIE	24,724	466.3992	99.06599	129.355	823.076
PV4SCIE	24,724	466.177	97.92099	133.91	845.497
PV5SCIE	24,724	465.373	98.09822	94.055	847.737
PV6SCIE	24,724	465.7415	98.42391	92.323	835.936
PV7SCIE	24,724	465.9503	98.32427	110.033	812.918
PV8SCIE	24,724	465.8664	98.00137	73.556	831.706
PV9SCIE	24,724	466.379	98.50421	102.011	837.476
PV10SCIE	24,724	465.5954	98.80506	116.197	837.871

Appendix 2 – Interaction tables

Need for Professional Development Scale

Table 14 Reading - Need for Professional Development Scale

VARIABLES	Reading Original	Reading OECD	Reading Teacher Experience	Reading Public School
Need for PD - Scale, t, c	0.0799	3.318	-2.841	-2.304
	(2.334)	(2.243)	(5.242)	(6.097)
Need for PD - Scale, t, c * OECD		-6.713		
		(4.384)		
Need for PD - Scale, t, c * Teacher Experience, t, c			0.187	
			(0.237)	
Need for PD - Scale, t, c * Public School, s				3.166
				(6.432)
OECD	26.80***	88.85**	26.15***	27.05***
	(8.427)	(40.37)	(8.640)	(8.236)
Teacher Experience, t, c	1.345*	1.293*	-0.347	1.366*
	(0.740)	(0.716)	(2.095)	(0.757)
Public School, s	-8.527	-9.434	-8.314	-38.08
	(11.55)	(11.80)	(11.62)	(62.22)
Observations	21,673	21,673	21,673	21,673
R-squared	0.310	0.312	0.310	0.310

Table 15 Mathematics - Need for Professional Development Scale

VARIABLES	Mathematics Original	Mathematics OECD	Mathematics Teacher Experience	Mathematics Public School
Need for PD - Scale, t, c	-4.227***	-1.986	-10.08***	-9.547**
	(1.524)	(1.988)	(2.535)	(3.786)
Need for PD - Scale, t, c * OECD		-4.322		
		(3.084)		
Need for PD - Scale, t, c * Teacher Experience, t, c			0.389**	
			(0.159)	
Need for PD - Scale, t, c * Public School, s				6.549
				(4.285)
OECD	38.25***	77.97***	40.37***	39.72***
	(10.41)	(29.87)	(10.19)	(9.663)
Teacher Experience, t, c	1.604***	1.530***	-2.051	1.620***
	(0.577)	(0.572)	(1.577)	(0.580)
Public School, s	-21.54**	-22.30***	-22.09***	-83.48**
	(8.481)	(8.315)	(8.162)	(40.02)
Observations	20,531	20,531	20,531	20,531
R-squared	0.359	0.360	0.362	0.361

Table 16 Science - Need for Professional Development Scale

VARIABLES	Science Original	Science OECD	Science Teacher Experience	Science Public School
Need for PD - Scale, t, c	-0.762	3.788*	-4.676	-1.990
	(2.111)	(2.220)	(4.475)	(6.833)
Need for PD - Scale, t, c * OECD		-7.023**		
		(3.510)		
Need for PD - Scale, t, c * Teacher Experience, t, c			0.239	
			(0.252)	
Need for PD - Scale, t, c * Public School, s				1.455
				(7.623)
OECD	5.068	68.49**	4.753	5.336
	(12.88)	(34.78)	(12.80)	(13.18)
Teacher Experience, t, c	1.641***	1.598***	-0.679	1.629***
	(0.577)	(0.550)	(2.550)	(0.586)
Public School, s	-17.68**	-16.74**	-17.48**	-31.41
	(8.399)	(8.448)	(8.593)	(74.73)
Observations	21,363	21,363	21,363	21,363
R-squared	0.305	0.307	0.306	0.305

Received Professional Development

Table 17 Reading including Teacher Experience dummy

VARIABLES	Teacher Experience
Teacher Experience, t, c	3.089***
	(1.094)
Received Professional Development, t, c	44.46*
	(26.85)
Received Professional Development * 5 < Teacher Experience < 10	-8.208
	(13.13)
Received Professional Development * 10 < Teacher Experience < 15	1.447
	(15.14)
Received Professional Development * 15 < Teacher Experience < 20	-7.744
	(21.07)
Received Professional Development * 20 < Teacher Experience < 25	-24.18
	(26.03)
Received Professional Development * 25 < Teacher Experience < 30	-34.32
	(30.69)
Received Professional Development * 30 < Teacher Experience < 35	-79.22*
	(40.64)
Received Professional Development * 35 <Teacher Experience < 40	-84.24**
	(40.33)
Received Professional Development * 40 < Teacher Experience < 45	-101.4**
	(45.97)
Received Professional Development * 45 < Teacher Experience < 50	-128.4***
	(47.52)

Table 18 Science including Teacher Experience dummy

VARIABLES	Teacher Experience
Teacher Experience, t, c	2.487**
	(1.021)
Received Professional Development, t, c	17.43
	(23.21)
Received Professional Development * 5 < Teacher Experience < 10	-2.126
	(13.85)
Received Professional Development * 10 < Teacher Experience < 15	9.556
	(16.20)
Received Professional Development * 15 < Teacher Experience < 20	14.45
	(20.44)
Received Professional Development * 20 < Teacher Experience < 25	9.259
	(24.54)
Received Professional Development * 25 < Teacher Experience < 30	-22.00
	(27.27)
Received Professional Development * 30 < Teacher Experience < 35	-27.29
	(34.20)
Received Professional Development * 35 <Teacher Experience < 40	-79.24**
	(38.90)
Received Professional Development * 40 < Teacher Experience < 45	-96.15**
	(44.20)
Received Professional Development * 45 < Teacher Experience < 50	-101.4**
	(46.85)