SCHOOL OF ECONOMICS AND MANAGEMENT

Bachelor Programme in Economy and Society

How to Improve Student Performance?

A look inside the box of teachers' education

by

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Abstract:

Improving the quality of education is imperative for economic development, and educating teachers has been seen as one of the main ways to increase educational quality. Yet, there is conflicting evidence about the importance or effectiveness of teacher's education to improve student outcomes. This text makes use of the TALIS-PISA link from the OECD to disaggregate teachers' education into the different elements included in it and to test the relationship between those different elements and student performance. Results show that general pedagogy has a positive association with academic achievement, and so does subject content to a lower extent. Yet the relationship is negative for elements such as training in how to teach cross-curricular skills or how to use ICT for teaching. Classroom practice during teachers' studies is also negatively associated with student outcomes. Other elements do not seem to have consistent statistically significant relationships across subjects. The results from this study may help motivate further research into the specific training that teachers must receive to become better educators and contribute to improve educational outcomes and economic development.

EGESO
Bachelor Thesis (15 ECTS)
June 2023
Supervisor: Kathryn Gary
Examiner: Ellen Hillbom
Word Count: 12,837

Acknowledgments

I would like to thank Kathryn, my supervisor, for her unvaluable contribution to this work. This study would look very different (and much worse) if it had not been for her hours spent reviewing my work and providing the most thorough and useful feedback; I thank her for her patience and her willingness to help and get the best out of me and my work. I was so grateful to have her as my supervisor.

I would also like to thank my girlfriend and my friends for their unconditional support, even when the stress of writing this thesis turned me into a grumpy ogre. They provided me with distractions when I needed them the most and with a wave of optimism and confidence in myself when I was lacking it. I think I would have gone mad without you being around me.

Finally, I would like to extend my gratefulness and love to my family who made all this possible. According to most research, family characteristics explain the largest variation in student performance and my case and privilege are no exception for this. Thank you for providing me with the tools necessary to be where I currently am and for your patience, waiting seven years of university studies until I finally delivered. Thank you for loving me and always taking care of me. I cannot imagine where I would be without your support.

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List of abbreviations

GPA	Grade Point Average
ICT	Information and Communication Technology
ISCED	International Standard Classification of Education
OECD	Organization of Economic Co-operation and Development
PISA	Programme for International Student Assessment
PV	Plausible Value
TALIS	Teaching and Learning International Survey

1. Introduction

It is widely agreed upon and empirically confirmed that education is essential for economic development due to its contribution to raising human capital and productivity (Becker, 1964; Benson, 1967; De la Fuente & Doménech, 2006; Demeulemeester & Diebolt, 2011; Hanushek & Woessmann, 2021; Mincer, 1984; Romer, 1986). It is also widely agreed upon that teachers have an essential role in the education process (Coleman, et al. 1966; Hanushek, 2011; Hanushek & Rivkin, 2010). Unfortunately, evidence has not been able to conclude which characteristics of teachers are the most important indicators of their quality and which have the largest effect on student performance (Hanushek, 2011). Despite the common assumption that improving teachers' education will improve their quality, empirical studies often arrive at contradicting conclusions, and a meta-analysis conducted by Hedges, Laine and Greenwald (1994) suggests that teachers' education (as measured in years or level of education) impacts student's performance negatively.

The purpose of this study is to look inside the box of teachers' education and explore how different elements of their training impact student performance to try to disentangle the issue. Therefore, this paper attempts to answer the following research question:

> ***How do different elements of teachers' education impact 15-year-old students' performance on the PISA test?***

This study makes use of the 2018 TALIS-PISA link from the OECD, a thorough, yet underutilized set of data which allows to combine student results in the Programme for International Student Assessment (PISA) with responses from teachers from the same school to the Teaching and Learning International Survey (TALIS). The sample used in this study comprises 27,055 students and 15,289 teachers from 944 schools in 8 countries: Argentina, Australia, Colombia, Czech Republic, Denmark, Georgia, Malta and Turkey. For the independent variables the study uses responses from teachers regarding the inclusion of 10 different elements in their education. For the dependent variables, students' test scores for mathematics, reading and science are used. A series of control variables at the student, teacher and school level are used to enhance the internal validity of the study against some extraneous variables. Relationships between the variables are tested using an input-output theoretical model and utilizing ordinary-least-squares regressions.

This study finds that students who attend schools where a higher percentage of the faculty has learned about general pedagogy fare considerably better than students in schools where less faculty members have acquired this knowledge. Similarly, schools with a higher proportion of teachers who have learned about their subject content during their studies seem to have better-performing students. Contrastingly, it seems that students enrolled in schools where a higher proportion of faculty members have learned how to use information and communication technology (ICT) for teaching and how to teach cross-curricular skills such as problem solving and critical thinking fare worse. It also seems that students tend to perform worse if they attend schools where a higher percentage of teachers have had classroom practice during their studies. The findings from this study call for further research into the specific mechanisms through which teachers enhance student performance. This, and following research on the topic may have important implications for the future of teachers' education programmes and on improvements in education overall.

The rest of this study is organized in the following manner: Section 2 presents the research problem and motivates the necessity for this study. Section 3 summarizes and discusses previous empirical findings on the way that teachers' skills and training affect student achievement. Section 4 discusses why these factors may be affecting student performance according to the theory discussed in the literature. Section 5 presents the datasets utilized for this study, as well as a discussion on the sample and variables chosen. Section 6 explains the methods used for the analysis and the different tests performed. Section 7 presents the results and summarizes them. Finally, section 8 discusses and concludes the study.

2. Research problem

Since Coleman and his colleagues published their report *Equality of Educational Opportunity* in 1966 (Coleman, et al. 1966), multiple researchers have tried to investigate the main factors that affect educational outcomes. Importantly, Coleman et al. (1966) discovered that students' background characteristics explain most of the differences in student achievement while schools play a relatively unimportant role. For this reason, a large body of research has attempted to investigate how students' background affects their achievement. This research has focused on students' socioeconomic status (Björklund & Salvanes, 2011; Nisbett, et al. 2012; OECD, 2019a; Sirin, 2005; Turkheimer, et al. 2003), the level of education of their parents (Black, Devereux & Salvanes, 2005; Burgess, 2016; Carneiro, Meghir & Parey, 2013; Chevalier, 2004; Holmlund, Lindahl & Plug, 2011; Oreopoulos, Page & Stevens, 2006), their immigration status (Akther & Robinson, 2014; Crosnoe & López Turley, 2011; OECD, 2016; OECD, 2019a, Tienda & Haskins, 2011), their age (Fredriksson & Öckert, 2005; Givord, 2020), their gender (Buser, Niederle & Oosterbeek, 2014; Buser, Peter & Wolter, 2017; Cai, et al. 2019; Griselda, 2020; OECD, 2004; OECD, 2019a; Ors, Palomino & Peyrache, 2013; Terrier, 2020), whether or not they have repeated a grade (Ikeda & García, 2004; Rumberger & Lim, 2008; Xia & Kirby, 2009), among other characteristics.

Even though Coleman and his colleagues found that schools characteristics were relatively unimportant compared to students' background (Coleman et al. 1966), interest in the effect of school characteristics on student performance did not halt. This may be partially explained by the fact that, while school characteristics can be more easily monitored and controlled by policymakers, changing students' background characteristics is more difficult, if not impossible. Therefore, the role of educational policy has been to improve schools in order to lift educational outcomes for everyone, regardless of their family background. Furthermore, school factors still explain around 21 percent of the difference in scores on standardized tests (Goldhader, Brewer & Anderson, 1999). School resources have a particularly large effect in poorer countries, indicating that there might be diminishing returns to school resources as countries develop (Gamoran & Long, 2007). Research on the influence of school characteristics on academic performance has explored the impact of private schooling (Abdulkadiroğlu, Pathak & Walters, 2018; Anand, Mizala & Repetto, 2009; Angrist, et al. 2002; Angrist, Pathak & Walters, 2013; Baude et al. 2020; Chudgar & Quin, 2012; Hanushek, et al. 2007; Lefebvre, Merrigan & Verstraete, 2011; Moulin, 2023; Thapa, 2015; Vandenberghe & Robin, 2004), the impact of schools' autonomy for managing their resources and teaching practices (Clark, 2009; Steinberg, 2014), the influence of the school's location (Chudgar & Quin, 2012; Fan & Chen, 1998; OECD, 2013), and its socioeconomic status (Caldas & Bankston III, 1997; Fan & Chen, 1998; OECD, 2012a; Sacerdote, 2011; Sirin, 2005), and while findings are mixed, it is clear that the role of schools is not negligible.

From all school resources, scholars tend to agree that teachers are one of the most important ones (Coleman et al. 1966; Hanushek & Rivkin, 2010; Hanushek, 2011). Some studies have investigated the value that teachers add to students by controlling for students' previous year achievement. A survey of these studies conducted by Hanushek and Rivkin (2010) argued that despite remaining methodological concerns, evidence suggests that teachers are important to boost student performance. "[T]he difference [between teachers] is truly large, with some teachers producing 1.5 years of gain in achievement in an academic year while others with equivalent students produce only 1/2 year of gain" (Hanushek, 2011, p. 467). When these differences are compounded through several years of studies, the gap between students who had mostly high-quality teachers and those who did not can grow tremendously.

Unfortunately, most large-scale empirical studies have not managed to identify specific teachers' attributes which reliably explain student outcomes (Hanushek, 2011). In fact, Goldhader, Brewer and Anderson (1999) found that less than 3 percent of the variation in students' outcomes caused by teachers is caused by observed variables such as a teachers' gender, race, level of education, years of experience, or certification, while the remaining 97 percent is caused by other unobserved variables. This implies that experience, certification, or education alone do not explain much of the variation in student performance. In terms of teachers' education, the problem is not only that the effect is small, but that the evidence is inconsistent. Hanushek (1986) surveyed a series of 106 studies that measured the effect of teacher's education on students' performance in the United States while controlling for family background. Out of the 106 studies, only 11 found a statistically significant relationship between both variables: 6 of them a positive one and 5 of them a negative one (Hanushek, 1986). On an updated version, which surveyed 171 studies, he found almost identical results (Hanushek, 1997). In other words, only one out of twenty studies confidently confirmed that teacher's education affected student performance positively, while the rest claimed either that it affected their performance negatively or it didn't affect them in any statistically significant way. Hedges, Laine and Greenwald (1994) used the same sample as Hanushek (1986) to do a meta-analysis and they argued that these studies suggest that there is a statistically significant relationship between the variables. Nevertheless, they found that, based on this sample of studies, teacher's education impacts student's performance negatively.

It is possible that the quantity of education received by teachers is less relevant than its quality, which might be the reason why there is conflicting evidence on the impact of teachers' education on academic achievement. Relatively few studies have looked at how different types of teachers' knowledge affect students' performance, nevertheless there is some evidence suggesting that pedagogical skills and differentiated teaching methods have a positive effect on student performance (Baumert et al. 2010; Hattie, 2009; Valiandes, 2015). However, research on this topic is lacking and the research that has been produced is often country-specific, or qualitative in nature, relying on case studies or observational research. Therefore the goal of this study is to contribute to the literature by providing a large-scale quantitative study on the relationship between these different types of teachers' knowledge and student performance. The hypothesis tested in this study is that different elements that teachers learn in their education have different effects on teacher quality and consequently different effects on student performance. While some elements that teachers learn in their studies might contribute positively to students' performance in standardized tests, some might not contribute to that end or might even affect student performance negatively. This might be causing the conflicting findings in the literature. Understanding how different elements of teachers' education affect student performance is imperative to improve teachers' training curricula and educational policy around the world.

3. Previous findings

This study attempts to look inside the box of teacher's education and explore if student performance is affected by ten different elements that teachers learn throughout their education. There are relatively few empirical studies which have tested these relationships. Yet, already in 1986, Strauss and Sawyer (1986) found evidence that teachers' subject content knowledge (measured by standardized tests) was associated with variations in students' failing rates and, to a smaller extent, their performance in reading and mathematics tests. Other studies have also found that teachers with higher subject content knowledge affected student outcomes positively (Hill, Rowan & Ball, 2005; Hill, et al. 2007). Yet, these studies did not distinguish between different kinds of teacher knowledge. The same is true for numerous other studies. D'Agostino and Powers (2009) made a meta-analysis of studies that use teachers' test scores or grade point average (GPA) to predict student performance and concluded that teacher test scores were moderately related to student performance at best.

Distinguishing between different types of knowledge from teachers is important since they need to know not only their subject matter but the most effective tools to transmit it. Baumert et al. (2010) used a test to determine teachers content knowledge and pedagogical content knowledge and found out that higher performance in pedagogical content knowledge explained 39% of the between-class variance in mathematics student performance, while content knowledge has much less predictive power. Voss, Kunter and Baumert (2011) developed an instrument to measure pedagogical/psychological knowledge and found that it was positively associated with indicators of instructional quality from the students' perspective. In addition, multiple studies have tested the effectiveness of different programmes of teachers' training in pedagogical skills, subject knowledge, and different teaching methods in improving student performance (Fennema, et al. 1996; Harbison & Hanushek, 1992; Mullens, Murnane

& Willett, 1996). Yet the geographical scope of these studies is limited or they are based on a qualitative or experimental method.

Few studies have explored whether the best ways to train teachers is through theoretical courses or through professional practices during their studies. Qualitative research suggests that beginner teachers tend to feel frustrated while trying to adapt to the differences between what they learned in their courses and what is required in the workplace (Adoniou, 2013; Kee, 2012). Furthermore, it has been shown that individuals enrolled in teacher training programmes place higher value on practice rather than theory and there is often a mistrust in research-based knowledge at the expense of knowledge acquired through experience (Thomm, et al. 2021; Whitney, Olan & Fredricksen, 2013). This has generated a demand for a higher weight of practical courses during teachers' studies, despite conflicting evidence on their effectiveness towards student performance (Adoniou, 2013). Case studies and qualitative research has shown that practical experiences differ vastly on their effectiveness for teacher preparation since the degree of congruence between the practicum and the workplace can be substantial (Kee, 2012; Shoffner, et al. 2010).

Since it is widely recognized that students within a classroom vary in their abilities and levels of development, attention has been given to the ways in which teachers manage to promote learning to all students within this mixed ability setting while ensuring that nobody is left behind. There is evidence that differentiated instruction techniques for students with different abilities increases students' performance (Hattie, 2009; Kim, 2005; McCrea Simpkins, Mastopieri & Scruggs, 2008; Muthomi & Mbugua, 2014; Valiandes, 2015) and that teachers who engaged in this type of teaching believed that in-depth training was necessary for them to develop these skills (Valiandes, 2015). Part of the research concerned with improving teaching methods suggests the use of cross-curricular skills such as critical thinking, self-assessment, teamwork, research design, etc. This is based on the ideas provided by psychologists, pedagogues, and recently, neuroscientists about how learning occurs (Barnes, 2015). Yet, testing the effects of teaching cross-curricular skills on student performance as measured by standardized tests is not common because these skills are believed to be better tested through different methods of assessment (Meijer, 2007).

The use of information and communication technology (ICT) for teaching has also been tested empirically with inconsistent results. While many studies have found that using technology in the classroom is associated with increased performance (Bai, et al. 2016;

Banerjee et al. 2007; Barrow, Markman & Rouse, 2008; Mo et al. 2014; Olibie, 2010), some others found negative or no association (Angrist & Lavy, 2002; Rouse & Krueger, 2004). It is likely that it is not the use of technology itself, but how it is used what matters in the classroom (Comi, et al. 2017), and the empirical evidence seems inconclusive regarding the comparative effectiveness of traditional and modern practices in teaching (Lavy, 2011; Van Klaveren, 2011), suggesting they might be complementary rather than substitutes. While ICT might be effective in teaching, it cannot replace the role of teachers in many of their tasks as educators.

Even though the literature has tested the impact of these different teaching practices, there has not been a study testing the relationships of all these elements together. Further, most studies have been country-specific, or even school-specific. This study makes an initial attempt to remedy the gap in the literature by making use of a large sample of teachers and students across eight countries, and testing the relationship between ten different skills that teachers acquire during their education.

4. Theory

The purpose of this section is to summarize some of the reasons why different elements in teachers' education are deemed important for students' development. There are many types of knowledge which are important for teachers to be effective at educating their students. In the 1980s, Shulman (1986, 1987) made a distinction between the three core dimensions of teachers' knowledge: content knowledge, pedagogical content knowledge, and generic pedagogical knowledge. According to Shulman (1986, 1987), teachers must have sufficient knowledge on the content of their subjects to be capable of not only defining to students the accepted truths in a domain, but to show why these are true, why it is worth acquiring this knowledge and how this relates to other disciplines in theory and in practice. Pedagogical content knowledge is deemed important since teachers need to know the most useful way of conveying certain topics by using distinct subject-specific methods, recognizing that some topics are more difficult than others (Shulman, 1986). Finally, generic pedagogical knowledge is important since teachers can learn strategies for classroom management, time management, knowledge about students and their learning, and knowledge about types of assessment, evaluation criteria, and how to monitor students learning to ensure nobody falls behind (König & Pflanzl, 2016; Shulman 1987).

Apart from these three core types of knowledge that teachers must have to be effective educators, research on cognitive psychology has been extrapolated to pedagogical studies and translated into theories on how to teach more effectively. Since it is widely accepted that students have distinct abilities for learning, special emphasis has been placed on training teachers on mixed ability methods for teaching (Valiandes, 2015). These methods are intended to promote effective instruction for all students through a process where teachers must adapt their teaching methods after monitoring their students' learning (Hattie, 2009, pp. 238-239). As Brunello and Brunello (2022) explain, these methods of differentiated instruction are also important to increase students' motivation by keeping lessons unpredictable and varied, increasing engagement with the curriculum. They claim that differentiated instruction for mixed ability classrooms allow students to learn at different rates through tasks with varying degrees of difficulty which they can decide how to solve. Choice ultimately gives students control over their learning which can increase their motivation and the effort they make to learn (Brunello & Brunello, 2022).

Another important set of teaching strategies in the pedagogical literature involves cross-curricular teaching. These strategies come from a socio-constructivist approach to education, which suggests that learning is context specific and self-regulated (OECD, 2012b). Cross-curricular strategies attempt to break down the boundaries between subjects by integrating them through collaboration between teachers and connecting themes taught in the classroom to the real world (McPhail, 2018). These strategies are usually intended to improve the capacity of children to solve problems, learning through collaboration, using their creativity, and improving their critical thinking (McPhail, 2018). One of the key principles of these cross-curricular approaches to learning is student input, where they decide on the direction of their learning together with the teacher, who serves as a guide that must know when and how to intervene, as well as when to hold back and allow children's curiosity to incentivize their learning (Fraser, 2013).

The use of information and communication technology (ICT) in education has figured in the education literature for many decades, and the debate about its effectiveness and some of the obstacles to its implementation continues (Bingimlas, 2009). Some authors argue that ICT has the potential of making education more efficient and interactive to students, increasing their motivation, and improving their performance (Bai et al. 2016; Lepper & Gurtner, 1989). Technology may also offer individualized instruction to allow students to learn at their own pace (Lepper & Gurtner, 1989). It is also possible that the availability of information online may contribute to satisfy students' diverse inquiries at their request (Lepper & Gurtner, 1989). Yet, it can also increase teachers' workload, decrease the effort they put into teaching, or create distractions for students (Bai et al. 2016). Overall, it is likely that the impact of ICT on student performance depends on the way ICT is used in the classroom (Comi, et al. 2017).

Finally, discussion has been abundant regarding the extent to which teachers' training should be practical rather than theoretical. As Adoniou (2013) explains, many consider practical courses essential to the formation of teachers, while others argue that practical experience tends to result in mimicry, and its effectiveness depends on the quality of the placement. Practical experience is often praised as providing education students with "real world" experience that the university lecture hall cannot provide. Adoniou's (2013) study shows that universities have a difficulty aligning the knowledge they provide with the skills that are necessary in practice. Yet, she also finds that experiences in practical placements vary and are also often misaligned with the skills that the real classroom requires. Still, prospective teachers place considerable value on these practical experiences (Adoniou, 2013; Thomm, et al. 2021; Whitney, Olan & Fredricksen, 2013)and, since the teaching profession is highly vocational (OECD, 2019b), understanding the motivations of individuals to become teachers is essential to shape their studies and avoid the typical frustration that first-time teachers experience when their expectations are not fulfilled (Adoniou, 2013). Teachers usually choose the educational career path because they want to influence children's development and contribute to society (OECD, 2019b), therefore restrictive school practices which do not allow teachers to have autonomy for instruction or assessment, may hinder their motivation and their job satisfaction and make them less-effective educators (Adoniou, 2013).

5. Data and variables

This research makes use of two datasets produced by the Organization of Economic Co-operation and Development (OECD): The Teaching and Learning International Survey (TALIS) and the Programme for International Student Assessment (PISA). Since 2013, the OECD has made it possible to combine these two datasets due to the existence of a school identification number, although the combination has some technical issues. Section 5.1 introduces the PISA programme, its methodology and some of its limitations. Section 5.2 does the same for the TALIS programme. Section 5.3 explains the TALIS-PISA link research design and the way in which the combination of both datasets must be undertaken. Finally, section 5.4 introduces the variables utilized in this study, as well as summary statistics about them.

5.1 PISA

The Programme for International Student Assessment (PISA) has been performed by the OECD periodically every three years since the year 2000. The programme is directed at 15-year-old students with the intention of assessing their reading, mathematics and science skills. The programme also collects information about the student's family background and their school environment as well as their views and attitudes regarding learning. This is done by administering questionnaires to the school principals and the student's parents. The number of countries participating in PISA has increased since the first round of the programme and in 2018 the test was administered to 612,004 students in 77 countries, both OECD and non-OECD members.

The methodology for PISA 2018 is explained thoroughly in the PISA technical report (OECD PISA 2018 Technical Report). Sampling was done using a two-stage stratified sample design. Firstly, schools were sampled in every participating country adjusting the probability of selection of each school by their size, where size was measured as an estimate of the number of 15-year-old students enrolled in the school. Before selecting these schools, they were assigned into mutually exclusive strata, in order to improve the representativeness of the population by ensuring selection from different regions, different types of funding, school types, etc. These criteria were selected on a country-specific basis. After randomly selecting the schools, the second stage involved selecting a random sample of 42 students from each institution to take the test. If the school had less than 42 students enrolled, all students were selected. Exclusions were allowed due to accessibility reasons at the country level or due to school and student-specific reasons such as disability or language barriers, yet the exclusion rate was set to be kept below 5% of the PISA desired target population for representative purposes. Similarly, response rates from schools and from students had to be kept above 85% and above 80% respectively to be deemed as an acceptable standard.

Once the students in the schools were selected, they were administered a 35-minutes background questionnaire and a 2-hours test. Perhaps the greatest limitation of the PISA test relies on it being a standardized test. Standardized tests typically ask the same questions to every student for it to allow a standard comparison, yet this is not the case for PISA which asks a different subset of questions to different students and creates a statistical estimate of their results using plausible values (PVs). This is done since the purpose of PISA is to evaluate a country's performance and not individual performance. While in most countries these tests were computer-based, this was not the case in all countries and score differences depending on whether the test taken was computer-based or not remain (Hopfenbeck, 2016). These differences may not reflect gaps in students' knowledge but the added difficulty and time-expenditure of writing paper-based tests. Furthermore, test items were a mixture of multiple-choice and open-ended questions. Some questions might be more difficult than others, and differences in country's performance may be due to increased difficulty of the test depending on the language in which it is applied (Hopfenbeck 2016).

Finally, and importantly, standardized tests measure one set of skills while neglecting others. It is possible, for example, that the PISA tests in mathematics, reading and science do not necessarily reflect students' learning of skills such as teamwork, critical thinking, etc. This is particularly important for the purpose of this research since different elements of teachers' education may still contribute to educational quality but not as it is measured by the standardized test. Furthermore, higher test scores may imply that teachers are actively teaching students how to solve the tests, rather than the actual knowledge that the subject entails. Some authors claim that standardized test results are associated with students' future outcomes such as their likelihood to go to college, which college they attend, their future income, their likelihood of having a child while being a teenager, and the quality of the neighbourhoods they live in (Chetty, Friedman and Rockoff, 2014b; Hanushek & Woessmann, 2008; Murnane, Willett & Levy, 1995). Nevertheless, Berliner (2020) argues that the validity of PISA as an explanatory variable of countries' economic performance is questionable. Berliner (2020) argues that all standardized tests scores tend to reflect demographic data rather than quality of schooling or instruction. For these reasons, it is important to bear in mind that this analysis explores the association between a school's faculty's training characteristics and results in the PISA test, and not necessarily on educational quality overall.

5.2 TALIS

The Teacher and Learning International Survey (TALIS) has been performed by the OECD periodically every five years since 2008. This programme focuses on gathering comparable information about teachers worldwide. Questionnaires are administered both to teachers and to school principals and it surveys them both on their beliefs and practices regarding their working environment, their profession, and their teaching, as well as on their professional background such as their qualifications and experience. Importantly, TALIS is not an assessment but a self-reported survey. In 2018, TALIS was administered to 261,426 teachers and 15,980 principals from 46 countries.

The methodology for TALIS is explained thoroughly in the TALIS technical report (OECD TALIS 2018 Technical Report). The target population of TALIS target population are teachers from primary, lower secondary and upper secondary education; therefore, countries were given the option to survey teachers from either of those levels. Additionally, countries were given the option to survey teachers in PISA participating schools. Special schools such as schools for adults and students with special needs were excluded from the list of eligible schools. From the list of eligible schools, 200 schools were selected randomly per country, and the questionnaires were administered to 1 principal and 20 teachers per school. Exclusions were allowed under certain circumstances but, similarly to PISA, ensuring that the response rate was kept above 85%. Questionnaires typically lasted between 45 and 60 minutes.

As mentioned previously, the TALIS questionnaires are not assessments, but rather self-reported surveys. This is the key limitation of this dataset due to the possibility of subjectivity affecting the reliability of the study. This is likely to be the case in questions regarding the overall teaching environment at the school, for example. This limitation is particularly important since teachers' responses to the elements included in their education do not necessarily reflect the extent to which they are trained in these elements nor the degree to which they utilize the skills acquired during their teaching practices. This limitation may be even more pronounced when the questions are translated into different languages since interpretation of the question may depend on language and cultural assumptions. For example, teaching in a mixed ability setting may be interpreted by some respondents as teaching for students with special needs while for others it may just mean that they recognize that different students learn at different paces and require different strategies in teaching. It is therefore important to interpret the results of this study under this context.

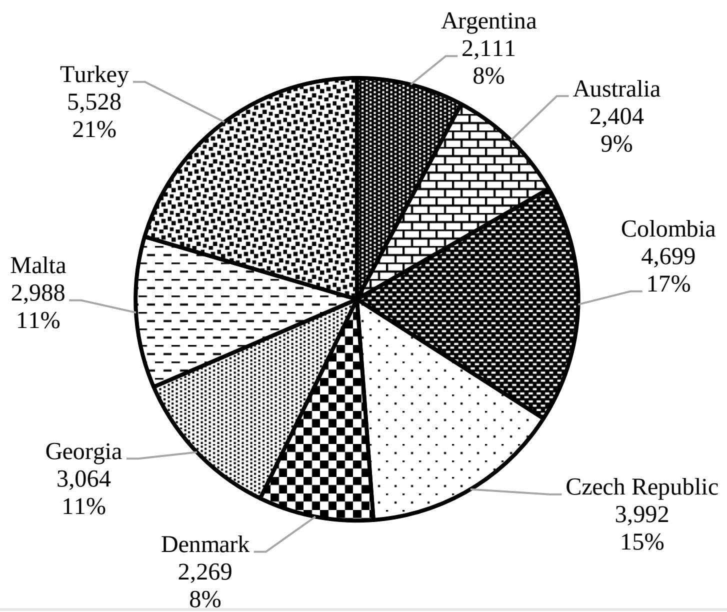
5.3 TALIS-PISA link research design

Combining the TALIS and PISA datasets is not entirely straightforward. To begin with, the combination must be done at the school level, and it is therefore impossible to assign individual students to their respective teachers (Cordero & Gil-Izquierdo, 2018; Gil-Izquierdo & Cordero, 2017). Consequently, teachers' responses must be aggregated into a mean school-level response. This makes it necessary to first identify the schools that participated in both the TALIS and PISA studies. Only certain countries opted to utilize a subsample of PISA 2018 selected schools for the TALIS 2018 study. These countries were Argentina, Australia, Colombia, Czech Republic, Denmark, Georgia, Malta, Turkey and Vietnam. Furthermore, during the adjudication process of PISA 2018, some irregularities were discovered in

Vietnam’s performance, so the OECD issued a recommendation to not include Vietnam’s scores in cross-country comparisons (OECD PISA 2018 Technical Report). For that reason, the sample used for this study was reduced to the remaining eight countries. Additionally, not every school within each of these countries participated in both studies so the sample was further reduced to those schools who did. The sample was reduced to 944 schools from eight countries.

Since the objective of the study is to measure the relationship between teachers’ training characteristics and their students’ academic performance, including teachers who started working in the school less than one year before the TALIS survey was conducted could affect the results despite the reduced contact hours that they might have had with the students, therefore teachers with less than a year of working experience in the school were excluded from the sample. The final sample for this analysis includes responses from 27,055 students and 15,289 teachers. The number and percentage of student observations per country is shown in Figure 1. The highest number of student observations comes from Turkey, Colombia, and Czech Republic (21, 17 and 15 percent of the observations respectively), while the lowest number of observations comes from Argentina, Denmark, and Australia (with 8, 8 and 9 percent of the observations respectively).

Figure 1: Number and percentage of student observations per country in the adjusted sample



Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

5.4 Variables

5.4.1 Dependent variables

Students are the unit of analysis for this study, therefore the dependent variables come from their results on the PISA test for mathematics, reading and science. Since the PISA test is designed to provide summary statistics about the population of a given country, the dataset uses 10 Plausible Values (PVs) per subject which are generated through multiple imputations based upon pupil's answers to certain subsets of questions. Averaging these PVs is not recommended since the measurement error at the individual level may be large (OECD, n.d). Cordero and Gil-Izquierdo (2018) circumvent this problem by only using one of the PVs, arguing that, in large samples, using only one does not make a difference. Indeed, the correlation between different PVs is strong, with coefficients around 0.88, 0.94, and 0.89 for math, reading and science respectively as shown in Appendix A. Because of this, and following Cordero and Gil Izquierdo's (2018) method, this analysis will also use only one of the PVs for each of the subjects as dependent variables.

Table 1 portrays summary statistics for student variables for both the original dataset with 612,004 observations and the adjusted sample of 27,055 students. As shown on Table 1, PVs for mathematics in the adjusted sample range between 120.97 and 844.83 while the original sample included cases in a larger range between 24.74 and 888.06. Yet the mean values are relatively similar (459.12 and 461.22) respectively. These trends are similar for reading and science where the mean in the adjusted sample resembles the mean of the original sample, but extreme cases are filtered out once most of the countries participating in PISA are removed. This suggests that the results from this analysis must be treated carefully, especially when trying to generalize the findings to countries with different levels of development or where PISA scores might be very different from the sample used here.

Table 1: Descriptive statistics of students explored in the analysis

	All observations (612,004 students)					Restricted sample (27,055 students)				
Number of schools	21,903					944				
Number of countries	77					8				
Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
Student results (Dependent variables)										
PV1MATH	606,627	461.220	104.359	24.743	888.064	27,055	459.117	98.939	120.973	844.826
PV1READ	606,627	456.123	108.048	0.000	887.692	27,055	461.779	102.693	120.243	837.275
PV1SCIE	606,627	460.694	102.665	58.736	886.081	27,055	464.380	99.061	122.363	827.421
Student controls										
Age	612,004	15.790	0.291	15.08	16.33	27,055	15.794	0.290	15.25	16.33
Gender (Female=1)	612,002	0.498	0.500	0	1	27,055	0.500	0.500	0	1
Repeater (Yes=1)	575,472	0.118	0.323	0	1	26,092	0.111	0.314	0	1
Immigrant (Yes=1)	579,436	0.061	0.240	0	1	25,777	0.029	0.168	0	1
Educational resources at home index	594,299	-0.199	1.108	-4.525	1.220	26,134	-0.201	1.076	-4.491	1.210
Economic, social and cultural status (ESCS) index	597,625	-0.281	1.116	-8.173	4.205	26,236	-0.410	1.202	-7.597	4.205

Notes: Original sample includes Albania, Azerbaijan (Baku), Argentina, Australia, Austria, Belgium, Bosnia and Herzegovina, Brazil, Brunei Darussalam, Bulgaria, Belarus, Canada, Chile, China (Taipei, Beijing, Shanghai, Jiangsu, Zheijang), Colombia, Costa Rica, Croatia, Czech Republic, Denmark, Dominican Republic, Estonia, Finland, France, Georgia, Germany, Greece, Hong Kong, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Kosovo, Japan, Kazakhstan, Jordan, Korea, Latvia, Lebanon, Lithuania, Luxembourg, Macao, Malaysia, Malta, Mexico, Moldova, Montenegro, Morocco, Netherlands, New Zealand, North Macedonia, Norway, Panama, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Saudi Arabia, Serbia, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay and Vietnam. Adjusted sample is based on schools also participating in TALIS 2018 and excluding Vietnam. This reduces the country sample to: Argentina (Buenos Aires), Australia, Colombia, Czech Republic, Denmark, Georgia, Malta and Turkey.

Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

5.4.2 Independent variables

The main objective of this paper is to analyse the impact that teachers, and specifically the elements included in their education, have on student performance. For this purpose, responses from 15,289 teachers were compiled and averaged at the school level in order to be combined with the student dataset, therefore reducing the number of observations to 944 observations at the school level. The explanatory variables selected were the responses to question 6A of the TALIS teacher's questionnaire (OECD TALIS 2018 Teacher Questionnaire). Question 6 was administered only to teachers who have a teaching qualification and teachers without it constituted a valid skip and are therefore registered as logically not applicable missing values. Question 6A is phrased in the following way: Were the following elements included in your formal education or training?

a) Content of some or all subject(s) I teach…

b) Pedagogy of some or all subject(s) I teach…

c) General pedagogy…

d) Classroom practice in some or all subject(s) I teach…

e) Teaching in a mixed ability setting…

f) Teaching in a multicultural or multilingual setting…

g) Teaching cross-curricular skills (e.g. creativity, critical thinking, problem solving)…

h) Use of ICT (information and communication technology) for teaching….

i) Student behaviour and classroom management….

j) Monitoring student's development and learning…

k) Facilitating students' transitions from <ISCED 2011 level 0> to <ISCED 2011 level 1>…

l) Facilitating play…

Sub-questions k) and l) were removed from this analysis since the Czech Republic and Denmark did not administer those questions and including them would reduce the sample further. Furthermore, question 6B which asks about the self-perception of preparedness for each of these elements was also not included in the analysis. Even though the question provides an interesting insight about the teachers' self-perception of their qualifications, its subjective nature made it lie outside of the scope of this thesis. Yet, further research could provide complementary insights into the findings obtained from exploring these variables.

Summary statistics for the teachers in the sample are presented in Table 2. All the independent variables are dummy variables where 1 is a positive response to the specific element being included in their teacher's education. The summary statistics for the independent variables remain true to the original sample after restricting the sample and aggregating responses at the school level. Importantly, some elements are more common in teachers' responses than others. While most teachers in the sample received training in subject content, subject pedagogy, and general pedagogy during their education (93, 91, and 95 percent of the observations respectively), teaching in a mixed ability setting, a multicultural or multilingual setting, and using ICT for teaching is less prevalent (35, 35, and 60 percent of the observations respectively).

Table 2: Descriptive statistics of teachers explored in the analysis

	All observations (261,426 teachers)					**Restricted sample (15,289 teachers)**					**Aggregated sample at school level (944 schools)**				
Number of schools	15,672					944					944				
Number of countries	46					8					8				
Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
PISA school ID	17,809					15,289					944				
Elements included in teachers education (Independent variables) Yes=1															
Subject content	254,526	0.930	0.256	0	1	14,834	0.927	0.259	0	1	944	0.931	0.095	0	1
Subject pedagogy	254,326	0.899	0.302	0	1	14,827	0.907	0.291	0	1	944	0.911	0.097	0	1
General pedagogy	254,074	0.926	0.262	0	1	14,811	0.945	0.228	0	1	944	0.944	0.086	0	1
Classroom practice	253,842	0.882	0.323	0	1	14,772	0.846	0.361	0	1	944	0.849	0.139	0	1
Teaching in a mixed ability setting	254,165	0.660	0.474	0	1	14,792	0.352	0.495	0	1	944	0.568	0.221	0	1
Teaching in a multicultural or multilingual setting	254,171	0.409	0.492	0	1	14,813	0.352	0.478	0	1	944	0.363	0.202	0	1
Teaching cross-curricular skills (e.g. creativity, critical thinking, problem solving)	254,138	0.713	0.452	0	1	14,804	0.708	0.455	0	1	944	0.705	0.190	0	1
Use of ICT (information and communication technology) for teaching	254,293	0.628	0.483	0	1	14,821	0.597	0.490	0	1	944	0.590	0.199	0	1
Student behaviour and classroom management	254,227	0.773	0.419	0	1	14,824	0.786	0.410	0	1	944	0.768	0.179	0	1
Monitoring students' development and learning	253,780	0.753	0.431	0	1	14,794	0.759	0.428	0	1	944	0.747	0.172	0	1
Teacher controls															
Having a postgraduate degree	245,644	0.385	0.487	0	1	15,197	0.448	0.497	0	1	944	0.468	0.361	0	1
Years of teaching experience	258,880	16.196	10.401	0	58	15,132	16.639	10.799	0	58	944	16.601	5.256	1.500	39.625
Index on perception of job satisfaction	252,546	12.110	2.033	3.268	16.551	14,705	12.030	2.006	3.650	16.002	944	12.039	0.773	8.487	15.301
Index on perception of co-operation among teachers	250,147	9.975	2.106	2.228	17.892	14,853	9.787	2.173	2.944	16.778	944	9.815	0.909	5.480	13.680
Index on perception of disciplinary climate	213,078	8.727	1.997	4.210	15.667	12,969	8.741	1.940	5.428	15.124	943	8.788	0.865	5.976	12.199

Notes: Original sample includes Argentina (Buenos Aires), Australia, Austria, Belgium, Brazil, Bulgaria, Canada (Alberta), Chile, China (Taipei, Shanghai), Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Hungary, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Lithuania, Malta, Mexico, Netherlands, New Zealand, Norway, Portugal, Romania, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Turkey, United Arab Emirates, United Kingdom (England), United States and Vietnam.

Adjusted sample is based on schools also participating in PISA 2018, excluding Vietnam and excluding teachers who have been working at their current school for less than a year. This reduces the country sample to: Argentina (Buenos Aires), Australia, Colombia, Czech Republic, Denmark, Georgia, Malta and Turkey. Aggregated sample at school level was built using the adjusted sample and calculating mean values for all the teachers belonging to the same school. The number of observations is therefore reduced to the number of schools in the sample, yet the participating countries remain the same.

Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

5.4.3 Control variables

Students' academic performance is likely to be influenced by a multiplicity of factors apart from the elements that their teachers learnt during their education. Introducing controls allows to improve the internal validity of the study by testing if an observed relationship between two variables is not mediated or enhanced by a third variable instead. For this reason, control variables were added to reflect unobserved country characteristics, as well as other teacher characteristics (aggregated at the school level). Additionally, controls for schools' characteristics and students' background were added to improve the reliability of the findings. The following subsections discuss these control variables.

5.4.3.1 Country controls

Different countries' educational outcomes can vary widely due to economic, political, social and cultural contexts which lie outside the scope of this study. Since the sample used in this analysis includes responses from eight diverse countries (Argentina, Australia, Colombia, Czech Republic, Denmark, Georgia, Malta, and Turkey), it is likely that educational outcomes vary widely between them due to reasons which are not considered in this study. Therefore, a fixed effect method was employed to control those country characteristics that cannot be observed in the analysis. This was done by adding categorical variables for the countries, using Denmark as the base. What this means is that these controls will measure how much of the variation in student outcomes can be explained by the nation where the school is located being different from Denmark. Country differences are therefore accounted for in the analysis but omitted in the discussion. Coefficients and p-values for the country categorical variables are excluded in the results but the bottom of the table indicates when they are controlled for and when they are not.

5.4.3.2 Teacher controls

A set of control variables for teachers was added since it is likely that other factors apart from the elements in their education have an impact on their teaching ability. The variables included as controls were having a postgraduate degree, their years of experience as teachers, their perception on job satisfaction, their perception on cooperation at the school and their perception on the disciplinary climate at the school. Summary statistics for these control variables are shown on Table 2 below the independent variables. Having a postgraduate degree is treated as a dummy variable were 1 is the possession of such qualification. 45 percent of the sample used in this analysis has a postgraduate degree, compared to 38 percent of the original sample, showing that the schools used in this analysis might have, on average, more educated teachers than the original TALIS dataset, reminding the reader once again that the results from this study must be interpreted in the context of its sample.

Controls for years of teaching experience were also added to the analysis, taking values between 0 and 58 and with a mean of 16.64 years. Furthermore, a variable for the years of experience squared was added in the regression analysis since it is likely that experience has diminishing returns to student performance instead of a linear effect. In other words, an extra year of experience might play an important role at the beginning, but it may have little effect on individuals who already have decades of teaching experience. Job satisfaction is used as a control based on the assumption that job satisfaction reflects commitment and love for teaching and a higher level of job satisfaction might improve students' scores by motivating them and improving the conveyance of knowledge and skills. Job satisfaction is measured using a composite index created by the OECD (OECD TALIS 2018 Technical Report) which compiles answers from teachers to 13 questions regarding their views on their working environment, the teaching profession, and their autonomy for determining course content, teaching methods and assessment. The values for the sample used in this analysis range between 3.65 and 16.00 with a mean of 12.03. Once teachers' responses are averaged at the school level, the values range between 5.48 and 13.68 with a mean of 12.04.

The perception on cooperation between teachers is used to control for the working environment in the school assuming that a higher level of cooperation will affect student outcomes positively. The teacher cooperation measure is a composite index created by the OECD (OECD TALIS 2018 Technical Report) based on teacher's responses to eight questions regarding the frequency of exchanges, discussions, teamwork and other joint activities with colleagues at the school. The values for cooperation perception in the sample of this study range between 2.94 and 16.78, with a mean of 9.79. Once these responses are averaged at the school level, they take values between 5.48 and 13.68 with a mean of 9.81. Finally, the perception of the disciplinary climate is used to control for perceptions on student behaviour at the school level, based on the assumption that schools with a worse disciplinary climate will affect students' learning negatively. The disciplinary climate is measured using a composite index built by the OECD (OECD TALIS 2018 Technical Report) based on teacher's responses to four questions regarding interruptions, noise and the learning atmosphere in the classroom. For the sample used in this study, the values range between 5.43 and 15.12, with a mean of 8.74. Once the teachers' responses are averaged at the school level, values range between 5.98 and 12.20 with a mean of 8.79.

5.4.3.3 School controls

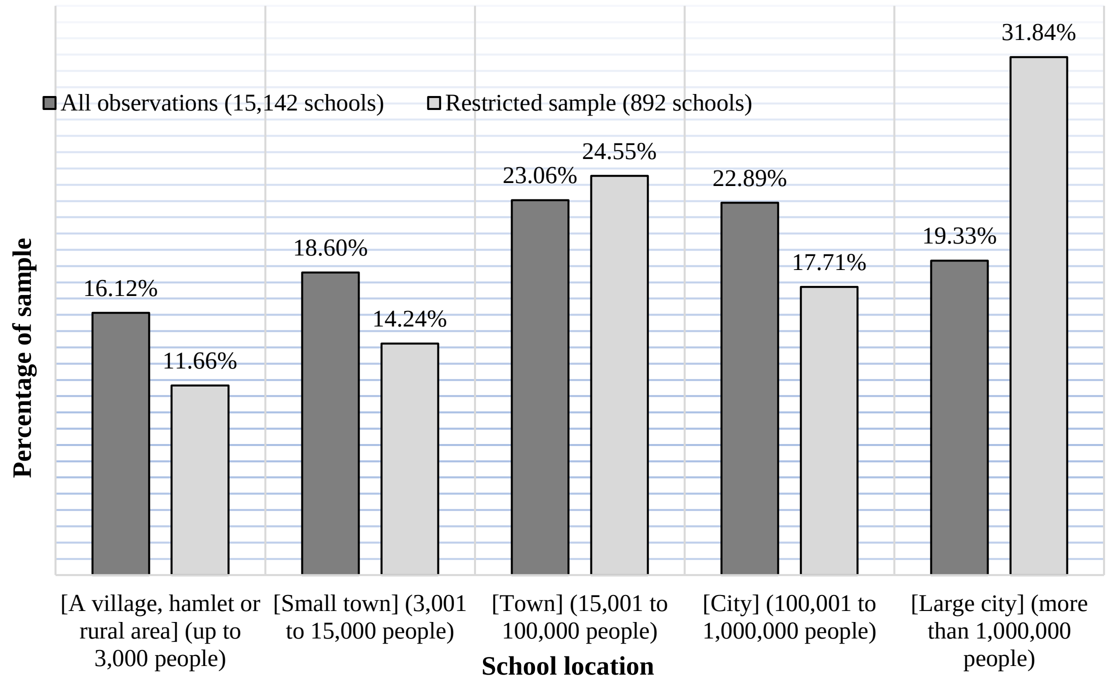
Differences in student performance can also be attributed to variations between schools in terms of the resources they receive and how they use them, as well as on their management, their accessibility and the average socio-economic level of the other students enrolled. For this reason, seven more controls were developed: The percentage of the school's total funding provided by the government, whether they are publicly or privately managed, the average ESCS index for the students in the school, the school's location, as well as three variables for a school's level of autonomy in terms of budgeting, instructional policies and curriculum creation. Summary statistics for these variables are presented in Table 3 and in Figures 2, 3, 4, and 5.

Table 3: Descriptive statistics of schools explored in the analysis

	All observations (15,980 schools)					Restricted sample (944 schools)				
Number of countries	46					8				
Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
PISA school ID	1,088					944				
School controls										
Percentage of school's total funding provided by the government	13,521	0.798	0.328	0	1	814	0.808	0.286	0	1
Privately managed school	14,527	0.216	0.412	0	1	890	0.237	0.426	0	1
Mean ESCS index	NA	NA	NA	NA	NA	934	-0.376	0.878	-4.060	1.417

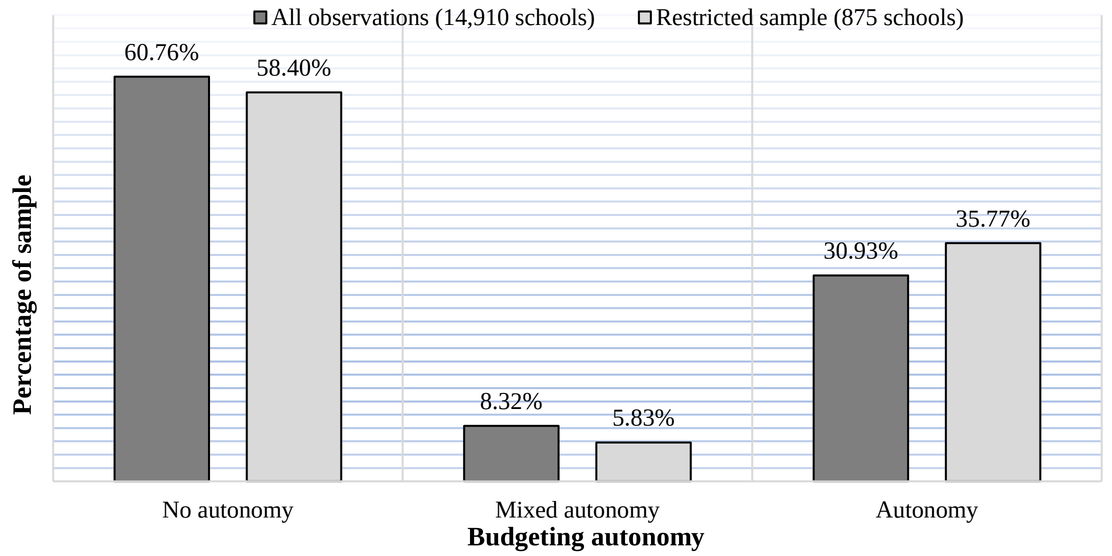
Notes: Original sample includes Argentina (Buenos Aires), Australia, Austria, Belgium, Brazil, Bulgaria, Canada (Alberta), Chile, China (Taipei, Shanghai), Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Hungary, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Lithuania, Malta, Mexico, Netherlands, New Zealand, Norway, Portugal, Romania, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Turkey, United Arab Emirates, United Kingdom (England), United States and Vietnam.
Adjusted sample is based on schools also participating in PISA 2018, excluding Vietnam. This reduces the country sample to: Argentina (Buenos Aires), Australia, Colombia, Czech Republic, Denmark, Georgia, Malta and Turkey.
Aggregated sample at school level was built using the adjusted sample and calculating mean values for all the teachers belonging to the same school. The number of observations is therefore reduced to the number of schools in the sample, yet the participating countries remain the same.
Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

Figure 2: Percentage of sample by school location



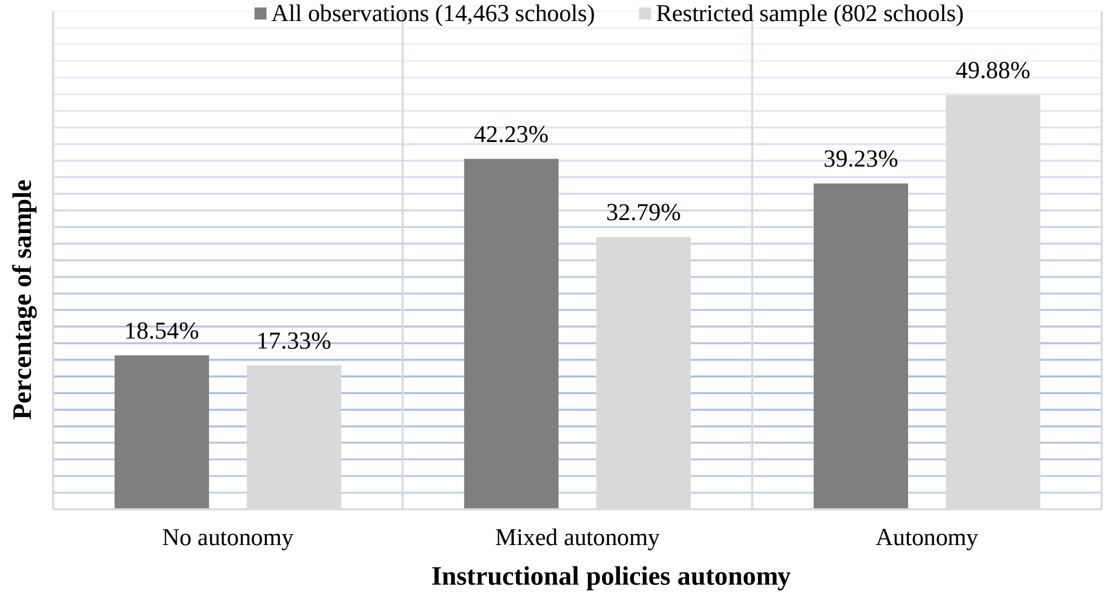
Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

Figure 3: Percentage of sample by autonomy for budgeting



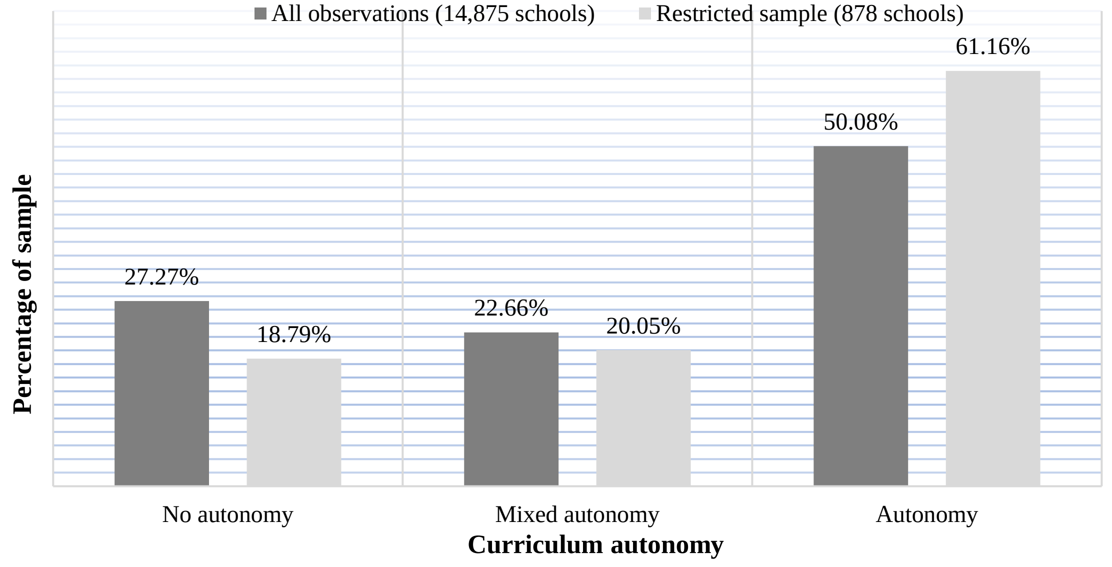
Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

Figure 4: Percentage of sample by autonomy for instructional policies



Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

Figure 5: Percentage of sample by autonomy for curriculum-making



Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

As seen in Table 3, the percentage of the school's funding provided by the government for the sample used in this study ranged between 0 and 100, and the average percentage of funding provided by the government was 81 percent, similarly to the mean percentage of government funding in the original dataset which was 80 percent. The management of the school was measured by a dummy variable where 0 indicates the school being publicly managed and 1 indicates the school being privately managed. In the adjusted sample 23.7 percent of schools were privately managed while only 21.6 percent of the schools in the original dataset were. The mean ESCS index was calculated with the intention of measuring the average socioeconomic level of the school. It was calculated by averaging student ESCS scores once the TALIS and PISA datasets were merged, therefore it is impossible to have a figure for schools in the original dataset. The values for the mean ESCS index range between -4.06 and 1.42 in the adjusted sample, and the average mean ESCS was -0.38.

The school's location was measured using a categorical variable which distinguished between the type of location based on the population of the area were the school was located. As seen in Figure 2, 11.66 percent of the schools in the adjusted sample were in villages, hamlets, or rural areas of up to 3,000 people, while 14.24 percent of the schools were in small towns of up to 15,000 inhabitants. Around 24.55 percent of the schools were in towns of less than 100,000 people and another 17.71 percent in cities of less than a million inhabitants. Most of the schools in the adjusted sample were in large cities with more than one million population (31.84 percent). School location proportions were considerably different from the original TALIS dataset. For example, only 19.33 percent of the schools in the original dataset were in large cities, compared to 31.84 percent in the adjusted sample. This might be due to an overrepresentation of urban children due to the Argentinian data which includes students only from Buenos Aires.

School's autonomy was measured using three different scale scores constructed by the OECD (OECD TALIS 2018 Technical Report): Autonomy for budgeting, autonomy for instructional policies, and autonomy for curriculum. Each of these variables was created based on principals' responses to several questions regarding who at the school had responsibility for certain tasks. If the principal replied that it was exclusively the governments' responsibility for more than half of the tasks, it was marked as no autonomy. If principals replied to more than half of the tasks that the responsibility relied on one or more stakeholders at the school but not to the government, it was marked as autonomy. If the principals indicated both stakeholders at the school level and at the government level as responsible for most of the tasks in the indicator, it was marked as mixed autonomy. As seen in Figure 3, most schools in the sample (58.4%) had no autonomy for budgeting, and only 5.8% had mixed autonomy, leaving 35.7% of schools in the sample having autonomy for budgeting. Figure 4 shows that autonomy for instructional policies follows a different pattern. Schools with autonomy for setting instructional policies constitute the largest group (49.9%), followed by those with mixed autonomy (32.8%), making schools without autonomy for instructional policies relatively rare in the sample (17.3%). Finally, as seen in Figure 5, most schools in the sample (61.2%) have autonomy for choosing the curriculum, followed by schools with mixed autonomy (20.05%). Schools with no autonomy for choosing the curriculum constitute 18.8% of the sample. School's autonomy controls were added as categorical variables in the analysis using the mode as the base (in the case of budget autonomy it was set at no autonomy, while in curriculum and instruction autonomy it was set at autonomy) For autonomy levels, coefficients and p-values are not shown in the results. Yet, the bottom of the table indicates when these variables are controlled for and when they are not.

5.4.3.4 Student controls

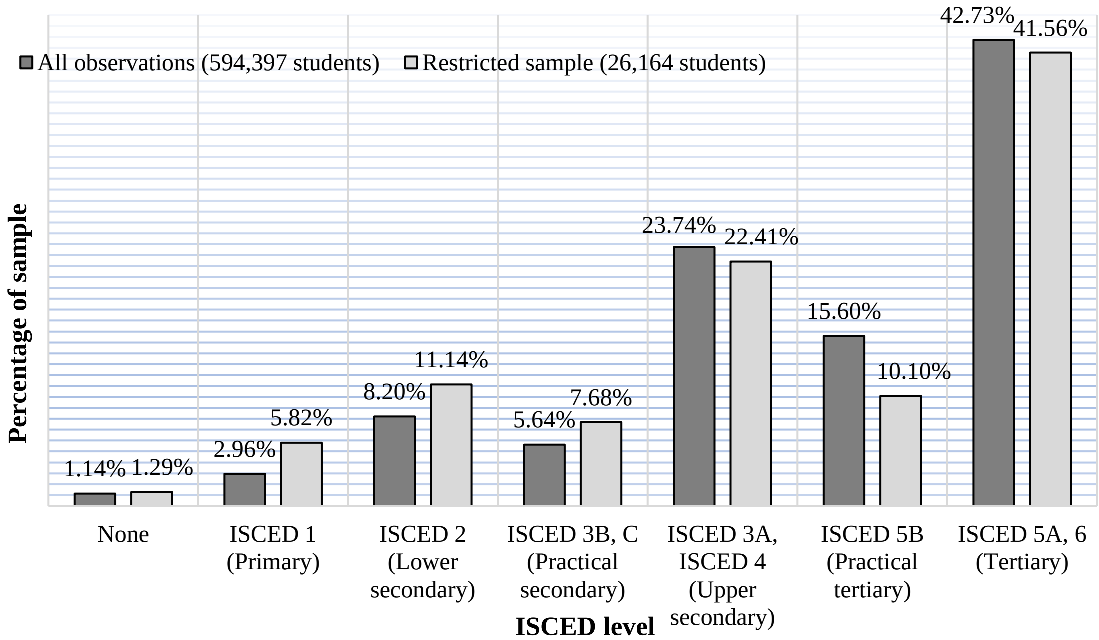
As mentioned before, some of the most important factors that explain variations in students' performance can be found at the individual student level. This study therefore controls for students' age, their gender, if they are grade repeaters, their immigrant status, the highest level of education of their parents, their educational resources at home and their economic, social and cultural status (ESCS).

As portrayed in Table 1 below the dependent variables, age in the adjusted sample varies between 15.25 and 16.33 years and the summary statistics remain similar to the original dataset. Gender is treated as a dummy variable where 0 is male and 1 is female. In both the original and the adjusted sample, the proportion between male and female students is similar. Grade repetition is also measured with a dummy variable were being a repeater is 1; only 11 percent of the sample falls in this category, compared to 32 percent in the original dataset. Immigrant status is also treated as a dummy variable where 1 is being a first-generation immigrant while 0 includes both native students and second-generation immigrants. This decision was made on the assumption that second-generation immigrants have less difficulty with language barriers and their parents have a larger familiarity with the system of the receiving country than their first-generation immigrant counterparts, especially since they must have been living in the country for at least fifteen years, due to their children's age when taking the PISA test. Only around 3 percent of the adjusted sample falls under the immigrant category, compared to 6 percent for the original sample.

Educational resources at home are intended to reflect the working environment of the students at home based on the assumption that a better environment will have a positive impact in their performance. Educational resources are measured through a composite index created by the OECD (OECD PISA 2018 Technical Report) based on item response theory (IRT) scaling methodology and including some material possessions at the student's home such as a desk to study at, a quiet place to study, a computer, books for studying or a dictionary. The values for this index in the adjusted sample range between -4.49 and 1.21 with a mean of -0.20, remaining similar to the original sample. The students economic, social and cultural status (ESCS) intends to reflect the socio-economic status of the student since data on household income is unavailable for the dataset. This variable was constructed by the OECD (OECD PISA 2018 Technical Report) based on the students' parents' occupation, education and home possessions, including the number of bathrooms at home, cars, televisions, and cultural items, as well as three country-specific items equally weighted and computed for comparability purposes against the whole set of economies participating in PISA. The values for the ESCS index range between -7.60 and 4.21 for this sample with a mean of -0.41, while the original sample had a slightly larger mean ESCS index of -0.28.

Finally, the highest level of education of their parents is a categorical variable which states the maximum between the mother's and the father's highest ISCED level of education due to the impact that parental achievement has on students' achievement. Descriptive statistics for the different categories of this variable are presented in Figure 6. Overall, it is possible to see that the adjusted sample used in this analysis is composed of students whose parents are less educated than on the original PISA database. More than 18 percent of the sample used is composed of students whose parents have less than upper secondary education completed. 1.29 percent of the students in the sample have parents without education, 5.82 percent have parents with only primary education, and 11.14 have up to lower secondary education. Only 12.3 percent of students in the original dataset fall into the same characteristics (1.14, 2.96, and 8.20 percent for no education, primary, and lower secondary education respectively). In the analysis, the highest level of parental education variable was treated as categorical, and the base level was set at no education since education can be considered incremental. Coefficients and p-values for highest parental education are not expressed in the regression tables but it is stated at the bottom of the table when they are controlled for and when they are not.

Figure 6: Percentage of sample by Highest Level of Parental Education (ISCED level)



Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

6. Method

This research makes use of an input-output approach or a production function of academic performance. This kind of method assumes that student performance (output) in a particular subject is a function of multiple variables (inputs). It can be expressed mathematically as:

$$Y_{ij} = \alpha_{ij} + \beta_{1j}TEE_{1j} + \beta_{2j}TEE_{2j} + \cdots + \beta_{10j}TEE_{10j} + \mu_j CNTRY_j + \gamma_j TchControls_j + \delta_j SchControls_j + \lambda_{ij} StuControls_{ij} + \varepsilon_{ij}$$

where Y_{ij} denotes student outcomes (as measured by PISA scores) for student i in school j. TEE_{nj} represents the percentage of teachers in school j who have had element n included in their education. $CNTRY_j$ is a control for the country where school j is situated. $TchControls_j$ is a vector of controls which includes average teacher characteristics aggregated at the school level for school j, including the percentage of teachers in the school holding a postgraduate degree; the average years of experience of the faculty; the average years of experience of the faculty squared to account for diminishing returns to experience; the mean perceptions of the faculty on job satisfaction; mean perceptions on cooperation among teachers; and average views on the disciplinary climate. $SchControls_j$ is a vector of other controls at the school level for school j, such as the percentage of the school's funding providing from the government; whether they are publicly or privately managed; the mean socioeconomic level of the school; whether the school is located on a rural area, a small town, a town, a city or a large city; the degree of autonomy for budgeting; for curriculum making; and for instructional policies. $StuControls_{ij}$ is a vector of controls at the student level for student i in school j , including the student's age; their gender; whether they are repeaters; their immigration status; their socioeconomic status; their educational resources at home; and their parents' highest level of education. Finally, ε_{ij} is an error term.

The main parameters of interest are $\beta_n$which denote the strength of the effect that different elements included in teachers' education have on student performance. However, there are two main limitations with this approach which should be considered. Firstly, and as previously mentioned, there is a possibility of PISA tests, and standardized tests in general, not reflecting the entirety of valuable measures of educational quality. Therefore, the results of this analysis must be interpreted bearing in mind that certain elements of teachers' education are associated with better or worse performance on the test, and not necessarily associated with an objective measure of educational quality.

Secondly, causal interpretation of this model would rely on an assumption of the relationship being monodirectional so that the differences observed in student performance do not affect the school characteristics in themselves, including the elements included in teachers' training. Therefore the β parameters could be biased. Controlling for other school characteristics partly alleviates this issue but the possibility of sorting bias remains. In other words, teachers with specific training characteristics may be deciding to work in schools with higher student performance or reputation instead of affecting the performance themselves. Chetty, Friedman and Rockoff (2014a), test the possibility of sorting bias affecting the results of standardized tests using a quasi-experimental research design and find that this bias is negligible when using value-added measures and controlling for student's background. Unfortunately, due to the cross-sectional nature of the datasets used in this analysis, it is impossible to use value-added measures and control for a students' previous year achievement. Even if this was possible, since the common unit of analysis in the datasets is the school and not the classroom, a value-added measure would test the impact of a school in a year, and not the effect of a particular teacher. This is a limitation that cannot be overcome due to the dataset in use, so results should always be interpreted in this context.

The model is tested in parts, adding one set of control variables to the model after each test, in order to observe the change in the parameters when controlling for additional factors. Every test is conducted one time separately for each subject: mathematics, reading and science. Test I is performed without controls, including only the elements of teachers' education TEE_{nj} as independent variables. Test II adds country controls $CNTRY_j$ using Denmark as the base to test if the differences observed might not be instead attributable to differences between countries. This is important especially since the scope of this analysis does not allow for an exploration of the effect of different country characteristics, and because teachers' training tends to differ between countries. Test III includes additional controls for teachers, aggregated at the school level $TchControls_j$ to control for other factors such as teachers' experience, their perception of their work environment and their level of education. Controlling for these factors is important to see if some of the variation attributed to the elements included in teachers' education are instead explained by other teacher factors. Test IV includes additional controls for school characteristics $SchControls_j$ to control for the type of management and funding that a school has, as well as their degree of autonomy, the mean socioeconomic level of the students and the location of the school. These factors are important to control since the way a school administers its resources and the environment in which it is situated may contribute to students' learning and take some of the explanatory power away from the elements in teacher's education, improving the reliability of the results. Finally, test V includes all controls by adding student control variables $StuControls_{ij}$ including individual and family background characteristics. These types of factors are often considered to have the largest effect on student performance. Consequently, controlling for students' background allows to observe if any impact previously observed from the elements included in teacher's education can instead be attributed to these characteristics instead.

7. Results

In this section, results of the proposed models are presented. Table 4 reports the results of the standard OLS models conducted in the analysis. Regressions have been conducted for all elements of teachers' education simultaneously but for each subject separately. Robust standard errors are shown in parenthesis. Significance levels are shown next to the parameters' values by stars, where three stars indicate a significance level greater than 0.01, two stars represent a significance level above 0.05 and one star indicates a significance level higher than 0.1. The number of observations used for each separate analysis is shown at the bottom of the table, as well as the adjusted coefficient of determination (R squared) which shows the explanatory power of the model.

7.1 Test I

Test I shows that the relationships between different elements of teacher's education and student performance are similar across the three different subjects, with the exception of the association between teachers learning how to monitor students' development and learning and students' science performance which is not statistically significant. Learning general pedagogy has the largest positive association with student performance across the three subjects with coefficients between 174.2 and 206.4. This implies that students who attend schools where ten percent more of the staff has learned general pedagogy perform between 17.4 and 20.6 points higher on PISA, depending on the subject. Schools where a higher proportion of the faculty has learnt their subject content and how to teach in a mixed ability setting are also related to higher student scores across the three subjects with coefficients between 43.6 and 62.9. There is not a statistically significant difference between students who attend schools with a higher proportion of faculty members trained in subject pedagogy and those who attend schools with a lower proportion, implying that this type of training has no relationship to student outcomes. The most surprising finding is perhaps that schools where the faculty had classroom practice during their studies or who learned how to teach cross-curricular skills such as critical thinking have a large negative effect on student performance with coefficients between -61.9 and -137.1. This implies that students who attend schools where 10 percent more faculty members have received training in these elements may perform between 6.2 and 13.7 points lower on the PISA tests. Other elements of teachers' education such as learning how to teach in a multicultural or multilingual setting, using ICT for teaching, classroom management and student behaviour, and monitoring students learning seem to also have a negative effect on student outcomes, although to a lower extent. Overall, the models in test I explain between 9.7 and 14.2 percent of the difference in student outcomes and the null hypothesis can be rejected for all of them at the one percent level.

Table 4a: Effect of different elements of teachers' education on student performance

	Test I			Test II			Test III		
	Math	**Reading**	**Science**	**Math**	**Reading**	**Science**	**Math**	**Reading**	**Science**
Elements included in education									
Subject content	48.534***	46.613***	43.587***	104.268***	113.012***	112.871***	74.923***	80.817***	82.401***
	(8.396)	(8.939)	(8.597)	(8.299)	(8.862)	(8.460)	(7.967)	(8.485)	(8.112)
Subject pedagogy	5.002	-2.086	-12.001	17.922**	31.868***	15.799*	2.095	14.285	-1.181
	(8.655)	(9.215)	(8.862)	(8.518)	(9.096)	(8.684)	(8.159)	(8.690)	(8.308)
General pedagogy	174.230***	206.413***	186.939***	39.638***	59.652***	39.118***	47.995***	69.211***	48.337***
	(9.698)	(10.325)	(9.930)	(10.134)	(10.822)	(10.331)	(9.706)	(10.337)	(9.882)
Classroom practice	-61.909***	-69.752***	-83.177***	4.873	6.918	7.662	-19.384***	-19.390***	-16.699**
	(5.823)	(6.199)	(5.962)	(6.660)	(7.112)	(6.789)	(6.390)	(6.806)	(6.506)
Teaching in a mixed ability setting	45.137***	62.928***	57.673***	-33.374***	-26.346***	-27.873***	-25.706***	-18.314***	-20.935***
	(3.884)	(4.135)	(3.977)	(4.364)	(4.660)	(4.449)	(4.206)	(4.480)	(4.283)
Teaching in a multicultural or multilingual	-23.537***	-37.228***	-37.711***	-8.720**	-15.003***	-13.390***	-3.527	-9.659**	-8.054*
setting	(3.867)	(4.117)	(3.959)	(4.149)	(4.430)	(4.230)	(4.096)	(4.362)	(4.170)
Teaching cross-curricular skills (e.g.	-137.122***	-102.268***	-106.399***	-21.630***	-18.791***	-15.871***	-21.865***	-19.139***	-16.636***
creativity, critical thinking, problem solving)	(4.350)	(4.632)	(4.454)	(4.886)	(5.218)	(4.982)	(4.676)	(4.980)	(4.761)
Use of ICT (information and communication	-33.619***	-20.830***	-18.174***	-34.805***	-42.017***	-39.261***	-12.057***	-16.710***	-15.093***
technology) for teaching	(3.936)	(4.191)	(4.030)	(4.202)	(4.487)	(4.284)	(4.291)	(4.570)	(4.369)
Student behaviour and classroom	-33.666***	-45.817***	-38.675***	3.823	.828	7.805	-8.573	-13.165**	-6.125
management	(4.740)	(5.046)	(4.853)	(5.580)	(5.959)	(5.689)	(5.359)	(5.707)	(5.456)
Monitoring students' development and	-26.391***	-14.008**	-9.158	-24.808***	-33.508***	-30.392***	-5.537	-12.742**	-11.074**
learning	(5.536)	(5.894)	(5.668)	(5.496)	(5.869)	(5.603)	(5.290)	(5.634)	(5.386)
Teachers' characteristics									
Having a postgraduate degree							-1.193	-5.647	-5.307
							(3.729)	(3.972)	(3.797)
Years of teaching experience							7.038***	7.262***	6.740***
							(.498)	(.530)	(.507)
Years of teaching experience squared							-.204***	-.208***	-.192***
							(.015)	(.015)	(.015)
Index job satisfaction							5.232***	3.963***	5.202***
							(.734)	(.782)	(.747)
Index on perception of co-operation among							-6.214***	-6.233***	-5.619***
teachers							(.644)	(.686)	(.656)
Index on perception on disciplinary climate							-28.702***	-32.485***	-30.083***
							(.696)	(.742)	(.709)
Country control	No			Yes			Yes		
School location control	No			No			No		
School autonomy controls	No			No			No		
Parental education control	No			No			No		
N	27,055	27,055	27,055	27,055	27,055	27,055	27,049	27,049	27,049
R squared (adjusted)	0.142***	0.097***	0.103***	0.224***	0.213***	0.195***	0.293***	0.256***	0.269***
Constant	445.402	394.495	434.048	411.321	365.120	382.064	644.626	649.414	626.572

Notes: Robust standard errors in parenthesis. Significance levels: *10 percent, ** 5 percent, *** 1 percent.
Country control base level: Denmark

Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

Table 4b: Effect of different elements of teachers' education on student performance

	Test IV			**Test V**		
	Math	**Reading**	**Science**	**Math**	**Reading**	**Science**
Elements included in education						
Subject content	12.915	21.098**	25.607***	15.427*	16.190*	26.428***
	(8.573)	(9.137)	(8.738)	(8.518)	(9.077)	(8.760)
Subject pedagogy	-2.525	7.337	-7.531	2.769	16.600*	-2.192
	(9.033)	(9.628)	(9.207)	(8.889)	(9.472)	(9.141)
General pedagogy	55.903***	86.205***	66.389***	49.689***	59.160***	53.475***
	(11.040)	(11.767)	(11.252)	(11.011)	(11.733)	(11.323)
Classroom practice	-11.150	-7.610	-8.530	-15.898**	-13.964*	-12.887*
	(6.829)	(7.278)	(6.960)	(6.693)	(7.132)	(6.883)
Teaching in a mixed ability setting	-14.964***	-.456	-6.479	-10.550**	-1.782	-2.462
	(4.741)	(5.054)	(4.833)	(4.667)	(4.973)	(4.799)
Teaching in a multicultural or multilingual setting	-5.965	-15.817***	-7.344	-6.273	-11.436**	-7.176
	(4.543)	(4.842)	(4.630)	(4.501)	(4.796)	(4.629)
Teaching cross-curricular skills (e.g. creativity, critical thinking, problem solving)	-18.961***	-16.562***	-11.836**	-23.195***	-16.955***	-15.066***
	(5.110)	(5.447)	(5.209)	(5.025)	(5.354)	(5.168)
Use of ICT (information and communication technology) for teaching	-11.605**	-18.978***	-19.385***	-8.844*	-14.090***	-14.672***
	(4.805)	(5.121)	(4.898)	(4.727)	(5.037)	(4.861)
Student behaviour and classroom management	3.921	1.761	3.997	6.543	.780	6.802
	(5.768)	(6.148)	(5.879)	(5.670)	(6.042)	(5.831)
Monitoring students' development and learning	13.677**	3.138	6.195	13.643**	7.071	6.835
	(5.680)	(6.054)	(5.789)	(5.612)	(5.980)	(5.771)
Teachers' characteristics						
Having a postgraduate degree	18.726***	17.207***	14.540***	24.084***	19.825***	18.092***
	(4.057)	(4.324)	(4.135)	(4.005)	(4.268)	(4.119)
Years of teaching experience	2.417***	2.349***	2.153***	1.655***	2.019***	1.651***
	(.551)	(.587)	(.561)	(.544)	(.580)	(.560)
Years of teaching experience squared	-.080***	-.081***	-.072***	-.057***	-.065***	-.054***
	(.016)	(.017)	(.017)	(.016)	(.017)	(.017)
Index job satisfaction	1.911**	1.312	2.649***	2.405***	1.245	2.748***
	(.789)	(.841)	(.804)	(.779)	(.830)	(.801)
Index on perception of co-operation among teachers	-7.321***	-8.012***	-8.031***	-7.293***	-7.366***	-7.920***
	(.715)	(.762)	(.729)	(.704)	(.750)	(.724)
Index on perception on disciplinary climate	-17.752***	-20.404***	-18.301***	-17.080***	-17.005***	-17.011***
	(.801)	(.854)	(.816)	(.800)	(.852)	(.822)
Schools' characteristics						
Percentage of school's total funding provided by the government	-10.995***	-18.019***	-10.445***	-11.264***	-15.415***	-10.411***
	(2.979)	(3.175)	(3.037)	(2.942)	(3.135)	(3.025)
Privately managed school	-4.182*	-4.611**	-2.414	-7.296***	-6.134***	-6.160***
	(2.136)	(2.277)	(2.177)	(2.114)	(2.253)	(2.174)
School's mean index of economic, social and cultural status (ESCS)	62.175***	63.296***	62.031***	47.212***	47.934***	47.717***
	(1.266)	(1.350)	(1.291)	(1.394)	(1.485)	(1.433)
Students' characteristics						
Age				9.900***	8.093***	8.435***
				(1.837)	(1.958)	(1.889)
Female				-15.761***	19.296***	-5.846***
				(1.067)	(1.137)	(1.097)
Repeater				-53.779***	-51.419***	-45.927***
				(1.925)	(2.051)	(1.979)
Immigrant				-4.632	-14.570***	-10.498***
				(3.491)	(3.720)	(3.591)
Educational resources at home				2.281***	1.747**	1.543**
				(.636)	(.677)	(.654)
Economic, social and cultural status (ESCS)				13.557***	15.964***	14.796***
				(1.066)	(1.135)	(1.096)
Country control	Yes			Yes		
School location control	Yes			Yes		
School autonomy controls	Yes			Yes		
Parental education control	No			Yes		
N	21,124	21,124	21,124	19,844	19,844	19,844
R squared (adjusted)	0.403***	0.361***	0.373***	0.447***	0.406***	0.407***
Constant	651.307	638.550	616.412	535.925	534.572	525.248

Notes: Robust standard errors in parenthesis. Significance levels: *10 percent, ** 5 percent, *** 1 percent.
Country control base level: Denmark
School location control base level: A village, hamlet or rural area (up to 3,000 people)
School autonomy controls base levels are based on the mode: For budget autonomy, the base level is no autonomy; for instruction and curriculum autonomy the base is autonomy
Parental education control base level: no education

Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations

7.2 Test II

Test II added categorical country controls using Denmark as the base. This was done to evaluate if the differences observed are caused by other factors at the national level instead. This is especially important since teacher training and the elements included in it differ between countries making it possible that most teachers who did not have a certain element included in their training belong mostly to the same country. Moreover, country characteristics which are independent of teachers and their training are likely to influence academic performance as well. After controlling for the country, all the coefficients of the explanatory variables are affected. While general pedagogy and subject content continue having the most important positive effects on student performance, their order of importance is inverted. While general pedagogy has coefficients ranging between 39.1 and 59.7, subject content has coefficients above 100 for all subjects, implying that students enrolled in schools where 10 percent more of the faculty has training in subject content are expected to perform more than 10 points better on each of the subjects of the PISA test. After country controls are added, subject pedagogy becomes statistically significant and positive, although the effect of subject pedagogy on mathematics and science outcomes is significant only at the 5 and 10 percent levels respectively. Interestingly, both classroom practice, and student behaviour and classroom management which used to have large negative associations with student performance before controlling for country differences, no longer have any statistically significant association with student outcomes after adding the country controls. This implies that the negative effect associated in test I to these variables is more accurately explained by differences between countries. The rest of the variables which used to be negative in test I, remain so, although the coefficients change. Importantly, learning how to teach cross-curricular skills does not have such a large negative effect after controlling for country differences, with coefficients ranging between -15.9 and -21.6. The models in test II gain explanatory power overall, with coefficients of determination between 19.5 and 22.4.

7.3 Test III

For test III, a set of controls for teachers TC_j aggregated at the school level was added. Adding this set of controls reduced the sample to 27,049 students since some schools did not administer questions about the disciplinary climate to their teachers. After adding this set of teacher controls, the parameters are affected deeply implying that some of the variation in student performance previously attributed to the elements teachers learned during their studies, may be attributable to other teacher characteristics instead. In particular, the faculty’s perception on the disciplinary climate seems to be largely and negatively associated with student performance across subjects, capturing some of the variation which was attributed to teachers' elements in education beforehand. The perception of co-operation among teachers also has a negative association with performance while both job satisfaction and years of experience are positively associated with student achievement. The model overall gains explanatory power with the coefficient of determination being between 25.6 and 29.3 percent.

After including teacher controls, subject content and general pedagogy remain having a strong and statistically significant positive association with student performance across subjects, yet the relationship with subject content is less strong after controlling for other teachers' characteristics. In particular, schools with 10 percent more faculty members trained in subject content perform around 7.5 points higher on mathematics, 8.1 points higher on reading, and 8.2 points higher on science. Similarly, schools with a 10 percent larger number of teachers trained in general pedagogy perform around 4.8 points higher on mathematics and science, and 6.9 points higher on reading. Results for teaching cross-curricular skills and teaching in a mixed ability setting remain similar after controlling for teachers' characteristics, continuing to be negatively associated with academic performance. Yet, classroom practice acquires negative statistical significance after teachers' controls are added. It seems to be that schools with 10 percent more faculty members with classroom practice included in their studies perform around 1.9 points worse on average in mathematics and reading and 1.7 points lower on science. The use of ICT for teaching remains negatively associated with student performance but the relationship is weaker, with coefficients between -16.7 and -12.1. The relationship between subject pedagogy and student performance loses statistical significance after controlling for teachers' characteristics. Finally, the relationships between student performance and the rest of the elements included in faculty members' training depends on the subject. While teaching in a multicultural or multilingual setting keeps being negatively associated with student performance, its coefficients are low and only statistically significant at the 5 percent level for reading and at the 10 percent level for science. Training in student behaviour and classroom management acquired negative statistical significance at the 5 percent level for reading only but it remains statistically insignificant for mathematics and science. Finally, the negative association between training in how to monitor students' learning and their performance became weaker after controlling for teachers' characteristics and it retained statistical significance at the 5 percent level only for reading and science.

7.4 Test IV

For Test IV, school control variables SC_j were added to the model. After adding these controls, the sample was further reduced to 21,124 observations and most parameters were heavily affected. The average socioeconomic status of the schools seems to capture a large part of the explanatory power of the model, since increasing the mean level by one point increases student performance by more than 60 points in every subject. The origin of the schools' funding also captures some of the variation in student outcomes, schools fully funded by the government perform around 10.4 points lower on science, 11 points lower on mathematics, and 18 points lower on reading. The relationship between some of the teacher controls and student performance also changes when controlling for school characteristics. Noticeably, a larger proportion of teachers with postgraduate education becomes positively associated with performance after adding school controls. Both the relationship between teaching experience and outcomes, and the association between the perception of the disciplinary climate and performance become weaker although they remain statistically significant. Adding school controls improves the explanatory power of the model, with coefficients of determination between 0.36 and 0.40, implying that more than a third of the variation between student scores can be explained by the observed school, teacher and country characteristics.

After controlling for school variables, the association between general pedagogy and student performance increases, with coefficients indicating that a 10 percent increase in the share of faculty members with this type of training increases student performance by 5.6, 8.6 and 6.6 points on mathematics, reading and science respectively. On the other hand, the relationship between subject content and performance becomes weaker after school controls, and it loses statistical significance in the case of mathematics. Teaching cross-curricular skills and using ICT for teaching remain relatively unaffected after adding school controls, by staying negatively related to student performance. Similarly, subject pedagogy and classroom management remain having no statistically significant relationship to students' results across subjects after controlling for school characteristics. For the rest of the elements, their influence depends on the subject. While learning how to teach in a mixed ability setting seems to be negatively related to student outcomes in all subjects, this influence is only statistically significant for mathematics. The equivalent is true about the impact of teaching in a multicultural or multilingual setting in the case of reading, which may imply that teachers who are trained in this regard are more likely to encounter classrooms with higher diversity in language skills, hence the negative impact. The effect of training teachers in how to monitor students' development and learning becomes positive after controlling for school characteristics, but the results are only significant at the 5 percent level for mathematics and insignificant for reading and science.

7.5 Test V

Test V incorporated all the variables specified in the model by including student background characteristics ST_{ij}. The sample was reduced by the addition of these variables to 19,844 students. Again, all parameters are affected by the addition of student controls and most of these controls have a statistically significant effect on student performance. In particular, being a grade repeater captures a large proportion of the variation in student performance. Repeaters perform around 53.4 points worse on mathematics, 51.4 points worse on reading and 45.9 points worse on science. Female students perform 19.3 points better in the PISA reading test than male students, but they perform 15.8 and 5.8 points worse in mathematics and science respectively. A higher socioeconomic status is also related to higher test scores, but the relationship is weaker than the one between the average socioeconomic status of the school. A higher age is also related to improved test scores with coefficients between 8.1 and 9.9 depending on the subject. Immigration status is negatively associated with students' performance only for reading and science with coefficients of -14.6 and -10.5 respectively, yet the relationship with mathematics test scores is not statistically significant. Finally, more educational resources at home are also associated with increased performance.

In terms of the teacher and school control variables, most of them remain having statistically significant relationships with test performance. Particularly strong relationships are found in the mean socioeconomic status of the school with coefficients between 47.2 and 47.9, and with the percentage of faculty members holding a postgraduate degree, with coefficients between 18.1 and 24.1. The relationships between performance and the perception of the disciplinary climate, teacher co-operation and job satisfaction remain relatively unchanged after controlling for student characteristics. Teaching experience continues to have a positive relationship with student performance, but to a lower extent, and the same is the case for the relationship between the percentage of the schools' funding provided by the government. One relationship that does change is the association between private schools and student performance, becoming significant and negative after the introduction of student controls. Students in private schools score between 6.1 and 7.3 points less on the PISA test depending on the subject.

The variables of interest in this study, namely the elements in teachers' education are also affected after introducing controls for students' characteristics, Training in general pedagogy continues to be strongly positively associated with student performance. Students attending schools where 10 percent more faculty members have training in general pedagogy score around 5 points higher on mathematics, 5.9 points higher in reading, and 5.3 points higher in science. The previously positive association between subject content and performance remains significant at the one percent level only for science while it is statistically significant only at the 10 percent level for mathematics and reading. Both teaching cross-curricular skills and the use of ICT for teaching continue to have negative relationships to student performance after controlling for students' characteristics, although the relationship between ICT and mathematics is only statistically significant at the 10 percent level. After adding student controls, classroom practice seems to be related to student outcomes negatively across subjects, although these relationships are only significant at the 5 percent level for mathematics and at the 1 percent level for reading and science. The coefficients imply that students attending schools where the faculty did not have classroom practice during their studies fare more than 10 points better on every subject on the PISA test. A higher proportion of teachers with training in subject pedagogy has a positive relationship to student scores only in reading and this relationship is only significant at the 10 percent level. Similarly, learning about monitoring students' development and learning is associated positively to student scores but this relationship is only significant at the 5 percent level in the case of mathematics and insignificant for reading and science. Learning how to teach in a mixed ability setting has a negative relationship with performance but the relationship is only statistically significant at the 5 percent level for mathematics and not significant for the other two subjects. Reading scores are negatively related to the proportion of teachers who have learned how to teach in a multicultural or multilingual setting, the relationship is also negative for mathematics and science scores, but it is not statistically significant. Finally, students in schools where teachers have learned about student behaviour and classroom management do not perform significantly better or worse than their peers in schools where teachers have not.

8. Discussion/conclusion

Despite consensus on the importance of teachers for students' learning, there is few evidence on what are the main characteristics of teachers linked to good performance. Indeed, empirical evidence exploring the relationship between teachers' education and student performance is inconclusive. Studies exploring different aspects of teachers' education and teacher skills are geographically limited or based on observation and qualitative evidence. This thesis made an initial attempt to dig inside the box of teachers' education and explore quantitatively if different elements included in the education of a school's faculty had different impacts on students' scores on reading, mathematics and science. The dataset used for this study was obtained by linking the PISA and TALIS datasets from the OECD and the sample consisted of 27,055 students and 15,289 teachers from 8 countries. The relationships were tested using ordinary-least-squares regressions where students' performance was considered a function of multiple variables including their family background, individual characteristics, the characteristics of their school, their country, and teachers' characteristics aggregated at the school level.

The findings of this study suggest that students perform differently on the PISA test when they are enrolled in schools where the faculty has been trained in different elements during their education, confirming the main hypothesis of this study. Some findings confirm the findings of previous literature. Students perform significantly better in schools where a higher percentage of the faculty learned general pedagogy during their studies, implying that teachers trained in these skills are better at transmitting knowledge by using adequate strategies depending on the task at hand (Shulman, 1986). Acquiring knowledge in the content of their subject is also positively related to student outcomes, especially in science. This may reflect the importance of understanding scientific knowledge in depth to be able to not only convey the accepted truth in a field but show the reason why this is the case and its relevance (Shulman, 1986). Learning how to monitor students' development and learning is associated with better test scores in mathematics, perhaps showing the importance of adapting teaching methods to the level of students. Finally, learning subject pedagogy is related to higher scores in reading, possibly confirming Shulman's (1986) intuition on the need to adapt learning materials to different types of knowledge within the subject.

The most intriguing findings concern those elements in teachers' education which are related to lower student performance. Students seem to perform worse when they are enrolled in schools where a higher percentage of the teachers have learned how to teach cross-curricular skills and how to use ICT for teaching. Yet, as discussed in the literature, it may be possible that these skills are not accurately assessed with standardized tests (Meijer, 2007). The use of ICT in teaching can be promising but it must be used as a complement to traditional teaching methods (Comi et al. 2017). It is possible that the findings of this study portray misuse of technology in the classroom which may be improved by increased teachers' training in ICT. The findings also suggest a negative association between practical studies and student scores, which may confirm authors concerns about the prioritization of practice over theory (Adoniou, 2013). Learning how to teach in mixed ability settings is related to lower scores in mathematics, and learning how to teach in multicultural or multilingual settings is related to lower scores in reading. Further research is required to understand the nature of these findings, but other factors may be playing a role. For example, it might be the case that more teachers learn how to teach in multicultural or multilingual settings when they are expected to encounter children who do not speak the language used at school fluently. The abundance of children with these characteristics might in turn explain low reading scores. Immigration controls were added to prevent some of these influences but the possibility of minorities native to the country driving these results cannot be ruled out.

It is important to remind the reader of some of the limitations that this research has. Standardized tests may not be the most appropriate tool to measure the influence of teachers' skills on educational outcomes. PISA in particular may be inadequate to observe school variations since its construction was based on the aim of making cross-country comparisons and not comparisons between schools. TALIS presents limitations since it is based on teachers' subjective responses and since the elements in which teachers are trained may not reflect their degree of preparedness, or the use of these skills in the classroom. Furthermore, the dataset utilized presented an additional difficulty by requiring an aggregation of teachers' characteristics at the school level. Better data and the use of value-added measures may improve these findings.

Despite its limitations, it is the hope of this study to motivate further research into an area that has been particularly neglected by researchers. Disaggregating teachers' education into different elements included in it might be a possible avenue to explore how teacher training programmes influence the quality of teachers. This could have long-lasting implications for public policy, influencing how to allocate resources that are channelled into the education of teaching staff. It has been shown that improving the quality of education is imperative for economic development, and targeting teachers' education can be a valuable tool for achieving an improvement of educational outcomes around the world. Understanding which factors are important for students' learning and which teachers' skills require improvement should be placed higher up on the agenda of researchers and policy makers.

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Appendix

Appendix A: Correlation Matrixes for PISA PVs

	PV1MATH	PV2MATH	PV3MATH	PV4MATH	PV5MATH	PV6MATH	PV7MATH	PV8MATH	PV9MATH	PV10MATH
PV1MATH	1.0000									
PV2MATH	0.8766	1.0000								
PV3MATH	0.8789	0.8775	1.0000							
PV4MATH	0.8763	0.8732	0.8762	1.0000						
PV5MATH	0.8775	0.8761	0.8786	0.8741	1.0000					
PV6MATH	0.8741	0.8749	0.8760	0.8733	0.8769	1.0000				
PV7MATH	0.8766	0.8772	0.8773	0.8750	0.8781	0.8753	1.0000			
PV8MATH	0.8745	0.8744	0.8753	0.8762	0.8765	0.8753	0.8754	1.0000		
PV9MATH	0.8760	0.8761	0.8773	0.8780	0.8760	0.8767	0.8771	0.8776	1.0000	
PV10MATH	0.8762	0.8740	0.8769	0.8728	0.8777	0.8760	0.8767	0.8760	0.8752	1.0000

	PV1READ	PV2READ	PV3READ	PV4READ	PV5READ	PV6READ	PV7READ	PV8READ	PV9READ	PV10READ
PV1READ	1.0000									
PV2READ	0.9382	1.0000								
PV3READ	0.9378	0.9372	1.0000							
PV4READ	0.9379	0.9374	0.9363	1.0000						
PV5READ	0.9364	0.9372	0.9365	0.9369	1.0000					
PV6READ	0.9382	0.9386	0.9382	0.9383	0.9374	1.0000				
PV7READ	0.9376	0.9369	0.9371	0.9379	0.9358	0.9373	1.0000			
PV8READ	0.9383	0.9380	0.9377	0.9384	0.9368	0.9383	0.9376	1.0000		
PV9READ	0.9373	0.9381	0.9375	0.9381	0.9370	0.9384	0.9371	0.9371	1.0000	
PV10READ	0.9377	0.9374	0.9381	0.9379	0.9369	0.9378	0.9374	0.9372	0.9380	1.0000

	PV1SCIE	PV2SCIE	PV3SCIE	PV4SCIE	PV5SCIE	PV6SCIE	PV7SCIE	PV8SCIE	PV9SCIE	PV10SCIE
PV1SCIE	1.0000									
PV2SCIE	0.8958	1.0000								
PV3SCIE	0.8975	0.8952	1.0000							
PV4SCIE	0.8936	0.8936	0.8944	1.0000						
PV5SCIE	0.8940	0.8956	0.8966	0.8940	1.0000					
PV6SCIE	0.8952	0.8956	0.8970	0.8942	0.8959	1.0000				
PV7SCIE	0.8962	0.8943	0.8969	0.8953	0.8951	0.8959	1.0000			
PV8SCIE	0.8951	0.8944	0.8968	0.8932	0.8927	0.8935	0.8930	1.0000		
PV9SCIE	0.8955	0.8961	0.8969	0.8940	0.8939	0.8947	0.8942	0.8942	1.0000	
PV10SCIE	0.8956	0.8959	0.8974	0.8945	0.8949	0.8967	0.8963	0.8946	0.8956	1.0000

Sources: OECD PISA 2018 Database, Available online: https://www.oecd.org/pisa/data/2018database/ [Accessed 14 February 2023], and OECD TALIS 2018 Database, Available online: https://www.oecd.org/education/talis/talis-2018-data.htm [Accessed 10 February 2023] Author's calculations