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Quality of Teaching and Learning in Science

Patrícia Dinis da Costa
Luísa Araújo

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Contact information
Name: Patricia Dinis Mota da Costa
Address: TP 582 – Via E .Fermi 2749 – I-21027 – Ispra (Va) - Italy
Email: patricia.costa@ec.europa.eu
Tel.: +39 0332 78 9173

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Title: Quality of Teaching and Learning in Science

Abstract
This report describes different teaching practices and the learning environment in the science classroom and their relation with students' achievement in European countries. Using PISA 2015 data, the results strengthen the evidence base and can inform policy initiatives that focus on high-quality teaching.

Contents

Note

This technical brief is part of the CRELL IX administrative agreement between DG Education and Culture (EAC) and DG Joint Research Centre (JRC). In particular, it refers to point 2.1 – Technical Report No 1 of the Technical Annex that accompanies the CRELL IX agreement.

Executive summary

Quality teaching and learning is linked to the structural and process characteristics of educational systems. Importantly, the role of education policies, of schools and of teachers in promoting high student performance is increasingly recognised (IEA, 2016; Hanushek & Woessmann, 2014). International large-scale surveys (ILSA) such as the Programme for International Student Assessment (PISA) allow us to envisage what is amenable to change beyond what is determined by culture and to consider reforms that improve learning conditions (Hanushek & Woessmann, 2014).

This report focuses on identifying the variation in different teaching practices in the science classroom and their relation with students' achievement. Using PISA data collected in the student and school questionnaires, the report offers an overview of the variations in teaching practices across European Union (EU) Member States (MS) and how they relate to students' achievement in science. For this purpose, we present univariate statistics for 28 EU MS[1]. More specifically, this report answers the following research question: What is the relationship between teaching practices, the learning environment and students' achievement in EU MS? Multilevel analyses are used for the PISA 2015 data available (considering both 20 EU MS and 16 EU MS) including the following different levels of analysis: country, school and students/classroom characteristics.

Teaching practices and the learning environment in science encompass inquiry-based teaching, teacher-directed instruction, perceived feedback, adaptive instruction, teacher support, disciplinary climate and ability grouping. With respect to inquiry-based science teaching, the results in this report show that this pedagogical approach can make a positive difference to students' achievement when a more basic level of scientific inquiry is considered. This is in contrast to previous findings that considered a composite measure of inquiry in the science classroom (OECD, 2016a). Thus, our analyses capture inquiry-based teaching instruction and its relation with students' achievement in a novel way and suggest that explaining how a science idea can be applied to different phenomena is an effective teaching practice.

The analyses provided in this report contribute to our understanding of the differences and similarities among countries and provide evidence regarding teaching effectiveness, giving an overview of what works well in the science classroom in EU MS. This information strengthens the evidence base and can be used at the EU level to share knowledge about good practices and to inform policy initiatives that focus on high-quality teaching (European Commission, 2016). Specific actions in this area are intended to help raise the skills levels of pupils and the workforce by

[1] For some analyses, data are not available for all 28 EU participating countries in PISA 2015, and results are presented for fewer MSs.

improving the effectiveness of education and training systems (European Commission, 2015).

Main findings

The main findings with clear policy relevance from this report are the following:

1) Univariate analysis

- Teacher-directed instruction is more frequently associated with higher achievement in science.
- In the majority of EU MS, there is a positive relationship between a higher frequency of inquiry, as measured by the teacher's explanation of how science ideas can be applied, and students' achievement in science.
- In all 28 EU MS, a better disciplinary climate is associated with higher achievement in science.

2) Multivariate analysis

- Teacher-directed instruction is positively associated with students' performance in science in 16 EU MS.
- Inquiry instruction, as measured by the variable "the teacher explains how an idea can be applied", favours students' achievement in science in 14 EU MS. The exceptions are Bulgaria and Estonia.
- Teachers' flexibility in adapting the lessons to students with different knowledge and abilities (adaptive instruction) is positively associated with students' achievement in science in 16 EU MS.
- A better disciplinary climate is associated with better student performance in science in all EU MS, except in France.
- In general, ability grouping within classes does not influence students' achievement in science.
- Accountability, namely the existence of external exams (assessments used to monitor the quality of education) in EU MS, is positively associated with students' performance in science.

1. Introduction and background

The Programme for International Student Assessment (PISA) captures the learning environment in science classrooms by asking students and school principals questions about the frequency of specific school science activities and related conditions for learning. In terms of teaching practices and the learning environment in science, the questions focus on teacher-directed instruction, inquiry-based instruction, teacher support and feedback, and disciplinary climate.

Teacher-directed and inquiry-based instruction refer to instructional practices that are specific to the way teachers teach science. The first encompasses well-structured and informative lessons that include teachers' explanations of concepts, classroom debates and students' questions (OECD, 2016c). The students have a predominantly passive role in the acquisition of this knowledge. In contrast, inquiry-based teaching refers to science activities that lead students to study the natural world and to explain scientific ideas by engaging in experimentation and hands-on activities (OECD, 2016c). Although the students have a predominantly active role during these activities, they are guided by their teachers, who ask leading questions and model the thought processes involved in science inquiry (Hanauer et al., 2009; OECD, 2016c). Thus, as defined in PISA, during inquiry-based teaching students are actively doing laboratory work and carrying out experiments. Nonetheless, inquiry-based teaching can also include teacher-directed aspects, such as asking students to make specific observations and reach predefined conclusions and/or requesting predictions and explanations of phenomena (OECD, 2016c; Wenning, 2007). As Hanauer et al. (2009, p. 21) put it, "The term scientific inquiry as manifest in different educational settings covers a wide range of diverse activities. The differences in types of scientific inquiry can be organized along a continuum according to the degree of teacher control and intellectual sophistication involved in each type of inquiry."

The more general conditions for learning are not specific to a given school subject or discipline and are regarded, in the school effectiveness literature, as general teaching effectiveness-enhancing factors (Kyriakides et al., 2014). These general effectiveness learning conditions should be considered in conjunction with specific teaching practices when trying to understand educational outcomes and related predictive factors (OECD, 2015). These include teacher support and feedback, which reflect the notions of differentiation and reinforcement in teaching, and disciplinary climate and its importance in understanding learning outcomes. For example, teachers believe that undisciplined, disruptive student behaviours prevent learning from taking place (OECD, 2014).

Previous studies that use data from international large-scale assessments (ILSA), namely CRELL's teaching practices report (Isac et al., 2015), pinpoint the positive relation between teachers' use of cognitive activation teaching strategies and students' achievement. Similarly, but in relation to innovative practices such as using digital supports for learning, research with TIMSS data suggests that using computers to look up ideas improves students' achievement (Falck et al., 2015). These are examples of different dimensions of teaching quality that have recently been investigated.

This report, on the quality of teaching and learning, builds on this knowledge base by considering teaching practices that are specific to science teaching, namely teacher-directed teaching and inquiry practices. Specifically, we used PISA 2015 data to examine the reported use of different science teaching practices and their relationship with students' achievement in science in participating European Union (EU) Member States (MS). To understand how they relate to students' achievement, we include other teaching effectiveness dimensions, such as teacher support and disciplinary climate. Moreover, we take into account student, classroom and school input factors (e.g. gender, socio-economic status, class size and ability grouping) to control for student background and structural system-level educational factors that may be related to science learning outcomes.

Given that in PISA 2015 the main domain assessed was science, these analyses provide insights about what works well in the science classroom in EU MS. This information strengthens the evidence base and can be used at the EU level to share knowledge about good practices and to inform policy initiatives that focus on high-quality teaching (European Commission, 2016). Specific actions in this area are intended to help raise the skills levels of pupils and the workforce by improving the effectiveness of education and training systems (European Commission, 2015).

2. The PISA 2015 assessment framework

Science literacy in PISA is defined as:

> the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically (OECD, 2016a, p. 13).

The PISA 2015 assessment framework is conceptualised to capture how science teachers teach science and how they use both teacher-directed instruction and inquiry-based practices (OECD, 2016a). The first relates to activities that are teacher centred or teacher initiated. For example, the teacher takes the lead and is the one who conducts experiments and asks questions. Accordingly, teacher-directed science instruction refers to the delivery of “clear and informative lessons on a topic, which usually includes teacher’s explanations, classroom debates and students’ questions” (OECD, 2016c, p. 63). Inquiry-based instruction is defined in the PISA assessment framework as the type of instruction that calls for real-life applications. The OECD (2016c) defines it as follows: “In science education, inquiry-based instruction is about engaging students in experimentation and hands-on activities, and also about challenging students and encouraging them to develop a conceptual understanding of scientific ideas” (OECD, 2016c, p. 69).

Nonetheless, the PISA definition of inquiry also refers to having students develop a conceptual understanding of scientific ideas. Accordingly, those activities that relate to real-life applications are also considered inquiry-based instruction, even if they are teacher directed or teacher initiated. Specifically, whereas in PISA “the teacher explains scientific ideas” is considered teacher-directed science instruction (OECD, 2016c, p. 63), “the teacher explains how a science idea can be applied to a number of different phenomena” is an inquiry-based practice (OECD, 2016c, p. 71).

3. Literature review

Quality in teaching and learning are linked to structural and process features of educational systems. The role of education policies, schools and teachers in promoting high student performance is increasingly recognised (Hanushek & Woessmann, 2014; IEA, 2016). ILSA such as PISA call attention to similarities and differences across different countries and highlight trends over time: “While some of those differences may be attributable to culture, the fact that the relationship has changed significantly in some countries suggests that policy and practice can make a difference” (OECD, 2013, p. 2). Furthermore, in terms of comparisons across countries, ILSA allow us to envisage what is amenable to change beyond what is determined by culture and to consider reforms that improve learning conditions (Hanushek & Woessmann, 2014). In terms of science teaching in PISA, evidence about what constitutes quality teaching is limited to the finding that, on average across OECD countries, using teacher-direct instruction more frequently is associated with higher science achievement, after controlling for the socio-economic status of students and schools (OECD, 2016c, p. 65). Conversely, “greater exposure to inquiry-based teaching is negatively associated with science performance in 56 countries and economies” (OECD, 2016, p. 71).

The PISA definition of inquiry in science teaching is about the students initiating science activities, such as designing their own experiments and raising their own questions for investigation. This reflects the notion that “students should engage in science using the same methods and approaches similar to those that scientists use to carry out scientific investigations” (Gee & Wong, 2012, p. 303). However, researchers have also found that student-led investigations may lack the kind of teacher-led instructional guidance that promotes learning (Flick & Lederman, 2004; Jiang & McComas, 2015). As Kirshner et al. (2006) suggest, if students are left on their own to solve problems and to independently select and carry out investigations, their efforts may be counterproductive. That is, their learning of scientific facts and ideas may be inhibited rather than enhanced because such inquiry-based processes place cognitive demands on students that they cannot handle.

Science inquiry in the literature about the teaching of science appears as “an umbrella term for a range of educational and professional activities within the sciences” (Hanauer et al., 2009, p. 15). Hodson (1996) notes that it is difficult to define science inquiry, because scientific inquiry is governed by a specific knowledge structure that involves the appropriation of specific concepts. On the one hand, there is consensus that inquiry-based science teaching is characterised by activities that are student initiated, for example:

- authentic and problem-based learning activities where there may not be a correct answer;

- a certain amount of experimental procedures, experiments and hands-on activities, including searching for information;
- self-regulated learning sequences in which student autonomy is emphasised;
- discursive argumentation and communication with peers ("talking science") (Jorde et al., 2012).

On the other hand, inquiry-based teaching may involve some teacher-led activities. Furthermore, meta-analyses that have measured the impact of both teacher-initiated and student-initiated science activities have found larger mean effect sizes for teacher-initiated activities than for those with student-led conditions (Furtak et al., 2012).

A clear dichotomy in instructional modes that are either teacher led or student initiated may nonetheless offer too narrow a view of what really happens in the science classroom and its relation with students' achievement. Indeed, research highlights this and offers empirical evidence that different levels of inquiry need to be considered to understand what quality of science teaching and learning looks like (Furtak et al., 2012; Minner et al., 2010). One approach is to consider a continuum in which at one end the teacher does all the activities and at the other the students do all the activities. For instance, Jiang and McComas (2015) examined the science achievement of 15-year-olds in PISA 2006 for all participating countries and found that the highest score was achieved at level 2 of inquiry-based teaching. This level reflects a balance between teacher-directed instruction and inquiry-based instruction in that students conduct activities and draw conclusions from data, but teachers design investigations and ask questions (Jiang & McComas, 2015).

A similar study with data for eight countries that participated in PISA 2006 reported that a higher frequency of investigations in science teaching and learning tend, on average, to be associated with lower achievement. However, in the same countries, students who reported high levels of participation in application models in science had higher science scores. As the authors conclude, hands-on activities related to the latter can be positively related to science achievement, but student-initiated investigations whereby students design their own experiments, choose an experimental design and test their own hypotheses are negatively associated with achievement in science (Valente et al., 2011).

As previously discussed, results from PISA 2015 (OECD, 2016c) indicate that an emphasis on inquiry-based teaching, as measured by an index composed of several variables, is negatively associated with students' achievement. In contrast, the index capturing teacher-directed instruction has a positive relation with achievement, and this is in line with research findings. Direct instruction models that are teacher centred encompass well-structured lessons and have been shown to have a positive impact on students' achievement (Mayer, 2004). Nonetheless, when considering only one of the variables in the index of inquiry-based teaching, “the teacher explains how a science idea can be applied to a number of different phenomena”, the OECD (2016c) finds that it is associated with a 12-point increase in students’ scores, after controlling for socio-economic status.

The conceptual framework of the Teaching and Learning International Survey (TALIS) also considers contrasting teaching beliefs and related instructional approaches, namely direct instruction and a constructivist view of teaching and learning. The assessment framework, which guided data collection in the first TALIS cycle in 2008 and the following one in 2013, addresses the differences between these two approaches as follows:

> The direct transmission view of student learning implies that a teacher’s role is to communicate knowledge in a clear and structured way, to explain correct solutions, to give students clear and resolvable problems, and to ensure calm and concentration in the classroom. In contrast, a constructivist view focuses on students not as passive recipients but as active participants in the process of acquiring knowledge. Teachers holding this view emphasize facilitating student inquiry, prefer to give students the chance to develop solutions to problems on their own, and allow students to play an active role in instructional activities (OECD, 2009, p. 92).

This description clearly shows that a direct transmission view of teaching equates to teacher-directed instruction and that a constructivist view equates to inquiry-based teaching, as defined in the PISA 2015 assessment framework (OECD, 2016a). Findings from TALIS show that teachers of reading, writing and literature at the lower secondary level (International Standard Classification of Education (ISCED) 2) reported using more structured teaching practices than student-oriented teaching practices or enhanced teaching activities. That is, they mainly structured their practices around stating learning goals, summarising former lessons, reviewing homework, checking exercise books and checking for student understanding. Enhanced teaching practices, such as assigning student debates, essays and projects, took place to a greater extent in reading lessons than in the science and mathematics lessons. With TALIS one cannot link this information with students’ achievement, as only teachers and school principals are sampled, but research suggests that in language education teaching practices that combine student-initiated activities with teacher-directed practices (such as delivering content in a lecture style) seem to be the most effective for learning (Creemers et al., 2013). Evidence even suggests that in some cases lecture-style teaching produces better learning outcomes. For example, Schwerdt & Wuppermann (2011) found a positive relation between more lecture-style presentation in the language classroom, as opposed to students’ working on projects, and students’ achievement.

To sum up, research based on data from international large-scale assessments does not offer a clear picture of which teaching practices or combination of practices are positively associated with student performance. Moreover, there may be differences in frequency of use and in the type of associations depending on the school subject. In fact, the effectiveness of different pedagogical practices may vary depending on the activities and content studied. In addition, one must bear in mind that, although teaching practices are process variables designed to capture the teaching and learning process, the PISA survey does not include classroom observations. These would be the means to capture the type and frequency of both generic and domain-specific teaching practices.

As captured in the last PISA 2015 assessment, the only inquiry-based science teaching practice that is positively associated with achievement pertains to a basic level of inquiry that is teacher initiated: "**The teacher explains how a science idea can be applied to a number of different phenomena**." This variable captures the delivery of science instruction in a particular way; the teacher delivers content knowledge by explaining how a science idea can be applied to different phenomena. Because inquiry-based science teaching presupposes real-life applications of knowledge (OECD, 2016a) this variable reflects inquiry, even if such inquiry is teacher initiated. In contrast, the variable "**the teacher explains scientific ideas**", which refers in the PISA reports to teacher-directed instruction, says nothing about the way the teacher explains scientific ideas. As previously discussed, the index that includes this and other inquiry-based teaching practices shows a negative association with students' achievement (OECD, 2016c). Other analyses of PISA data, namely that of the 2012 round, indicates that in the mathematics classroom asking students how they solved a problem, to apply what they have learned to different contexts, and to reflect on a problem and giving them problems that require thinking for an extended time is related to higher scores (Costa & Araújo, 2015). The OECD (2016c) reports similar results for this PISA 2012 round focusing on mathematics: higher achievement for students who reported greater exposure to this kind of cognitive activation in PISA 2012. In contrast, students who perform at lower proficiency levels tend to report that their teachers engage more in teacher-directed instruction.

In exploring the relationship between teaching quality and educational outcomes (OECD, 2014), as previously mentioned, we need to consider specific teaching practices in conjunction with general teaching effectiveness-enhancing factors (Kyriakides et al., 2014; OECD, 2014). Even if establishing cause and effect relationships between teaching effectiveness factors and students' achievement remains difficult, it is clear that approaches to teaching and learning go hand in hand with specific pedagogical practices that can be influenced by the surrounding context. In particular, the pedagogical stance of the teacher is important for students' achievement. As Hattie (2009, p. 2) states, content-specific knowledge is not enough to be a successful teacher. It is equally important to establish “clear learning intentions and success criteria, a classroom environment that tolerates errors, and tasks for students that are challenging but commensurate with their abilities”.

Thus, regarding other factors related to learning environment conditions, the literature shows that attending schools with a better disciplinary climate positively affects students’ scores (Costa & Araújo, 2015; Martin & Mullis, 2013). The same is true for adaptive instruction (Gomendio, 2017). Teacher support is relevant for both teaching practices and students’ achievement (Isac et al. , 2015). Several studies also reveal that student performance is higher when students receive feedback from teachers (Hattie & Timperley, 2007; Lipko-Speed et al., 2014).

With respect to other factors that may be related to educational outcomes, the literature suggests that in addition to student and family background characteristics, we should consider country and educational system-level characteristics. For instance, a country’s economic wealth, educational tracking or ability grouping, school autonomy, accountability and teachers’ qualifications have been shown to relate to student performance.

First, economic wealth can contribute to explaining country disparities. The literature shows that more wealth is associated with higher educational achievement (Barber, 2006; Hanushek & Woessmann, 2014; OECD, 2010). However, similar wealth across different countries is also associated with educational disparities, and the driving mechanisms that underlie them are not well understood (Vettenranta & Harju-Luukkainen, 2013). Second, a recurrent finding is that educational tracking increases the achievement gap between students from disadvantaged backgrounds and those from more advantaged backgrounds (Hanushek, 2011; Hanushek & Woessmann, 2014). Third, accountability coupled with school autonomy, on the other hand, seems to promote more equitable education outcomes (Hanushek & Woessman, 2014). That is, systems in which students take national exams tend to perform better and when this accountability feature is present alongside school autonomy (e.g. where schools make decisions regarding choice of textbooks or the hiring of teachers) performance is also better (Hippe et al., 2016).

Findings are less clear regarding teachers’ qualifications, mainly in terms of whether they are fully certified to teach a given subject, but studies suggest that qualification makes more of a difference for student performance than experience. This is most probably the case because teachers become more effective in their initial years, but beyond that their experience does not have a significant impact on students’ achievement (Schwerdt & Wuppermann, 2011). A recent report with cross-country comparisons corroborates this evidence and documents that in recent years many countries have put an emphasis on upgrading teachers’ qualifications (IEA, 2015), but that “there is no simple, universal relationship between teacher experience and student achievement" (IEA, 2015, p. 3).

4. Purpose of the report

This report uses data from PISA 2015 to identify the variation in different teaching practices in the science classroom and their relation with students' achievement. Specifically, using information from the student and school questionnaires, the report gives an overview of the variations in teaching practices across EU MS and how they relate to students' achievement in science. For this purpose, we use univariate statistics. In addition, it explores the proportion of variance in students' achievement that can be explained by the use of different teaching practices. Finally, the report also aims to answer the following research question: What is the relationship between teaching practices, learning environment and students' achievement in EU MS? A multilevel analysis is used for the available PISA 2015 data, which includes different levels of analysis. These analyses contribute to our understanding of the differences and similarities among countries and provide evidence regarding teaching effectiveness.

5. Data source

The PISA was launched in 2000 by the Organisation for Economic Co-operation and Development (OECD). Since then, the OECD has been running this ILSA of 15-year-old students' skills in mathematics, science and reading every three years. Each PISA assessment cycle has a main domain, which was mathematics in 2012 and science in 2015 and which will be reading in 2018. In fact, PISA is a cognitive test that measures knowledge of a given subject matter studied in school and is in many ways different from content-based tests. Content-based tests are those that focus on testing the curriculum learned at school (Araújo et al., 2017). PISA is designed to measure students' ability to use or apply the knowledge acquired in school to solve problems they might encounter in everyday life. As such, it captures the ability of 15-year-olds to either enter the work force or pursue further studies (OECD, 2009).

In PISA, students' test scores in mathematics, science and reading, are computed according to item response theory (IRT) and standardised with an OECD mean of 500, set in the first cycle of the survey, and a standard deviation of 100.

As is widely recognised by educational stakeholders – decision-makers, teachers, students, parents and the general public – PISA offers comparative indicators of students' achievement and has been used to monitor educational systems worldwide. One of the central purposes of PISA is to collect and report trend information about students' performance in reading, mathematics and science, thus enabling countries to monitor their progress in meeting key learning objectives.

Importantly, PISA has been used to assess student learning outcomes since 2000 and is used every three years in many OECD and non-OECD countries and economies. Forty-three countries participated in the first assessment cycle, 41 in the second cycle in 2003, 57 in the third cycle in 2006, 75 in the fourth cycle in 2009 and 65 in the fifth cycle in 2012. In the latest PISA assessment, which took place in 2015, 72 countries and economies participated (OECD, 2016b). All 28 EU MS participated in this last assessment (Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Cyprus[2] (CY), the Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL),

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[2] Notes regarding Cyprus:

"Note by Turkey: The information in this document with reference to 'Cyprus' relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the 'Cyprus issue'.

Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus." (OECD, 2016, V.1, p. 27).

Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), the Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE) and the United Kingdom (UK)).

In addition to the results of students' performance in science, PISA also gathers contextual information through the application of questionnaires[3] to the students and to school principals (OECD, 2016a, p. 15). More specifically, as defined by the OECD, the questionnaires cover the following aspects:

• "Aspects of students' lives, such as their attitudes towards learning, their habits and life in and outside of school, and their family environment.

• Aspects of schools, such as the quality of the schools' human and material resources, public and private management and funding, decision-making processes, staffing practices and the school's curricular emphasis and extracurricular activities offered.

• Context of instruction, including institutional structures and types, class size, classroom and school climate, and reading activities in class.

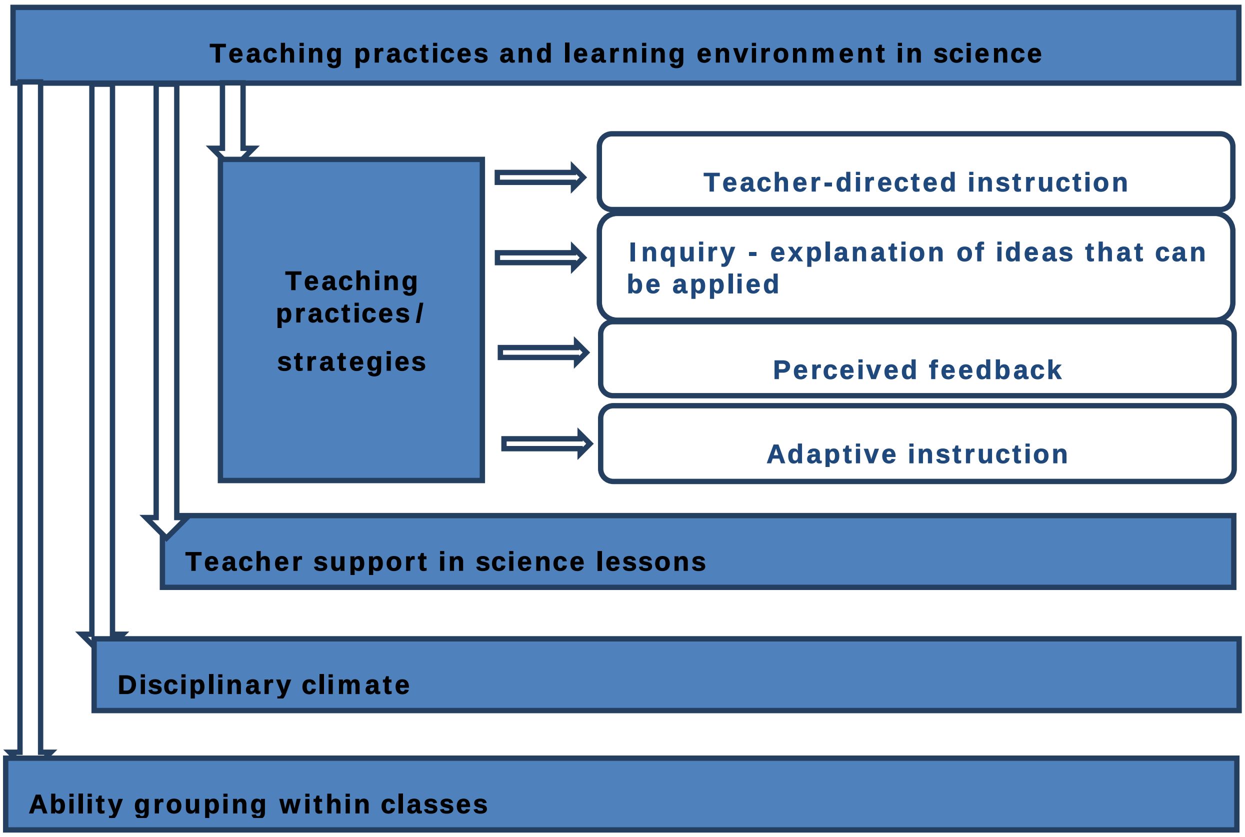
• Aspects of learning, including students' interest, motivation and engagement." (OECD, 2016a).

[3] Four additional optional questionnaires were offered in PISA: a computer familiarity questionnaire, an educational career questionnaire, a parent questionnaire, and a teacher questionnaire.

6. Variables measuring teaching practices and learning environment in science

PISA 2015 captures the learning environment in science classrooms by asking students questions about the frequency of specific school science activities and related conditions for learning. We followed a theoretical model based on the PISA 2012 taxonomy of educational outcomes and predictive factors[4] (OECD, 2016a) and on the PISA 2015 teacher questionnaire framework[5]. Accordingly, our variables focus on teaching practices/strategies, teacher support, disciplinary climate and ability grouping. While teaching strategies are specific types of instructions that capture how teachers teach science, the others are general effectiveness-enhancing factors (Figure 6.1). The OECD (2016c) groups teaching practices/strategies for science into four approaches: teacher-directed instruction, inquiry-based instruction, perceived feedback and adaptive instruction. These approaches are based on questions, from the PISA 2015 students' questionnaire, asking how often specific activities happened in the science classroom (hence, the OECD uses information from the students' questionnaire in relation to students' perception of their teachers' instructional practices across EU MS).

Figure 6.1. Teaching practices and learning environment in science



[4] See https://www.oecd.org/pisa/pisaproducts/PISA-2012-technical-report-final.pdf, p. 49.
[5] See https://www.oecd.org/pisa/pisaproducts/PISA-2015-draft-questionnaire-framework.pdf, p. 22.

The OECD created the following indices for teaching practices (aggregated measures):

- teacher-directed instruction;
- perceived feedback;
- adaptive instruction;
- teacher support to students; and
- disciplinary climate.

Higher values for these indices indicate that the activities/practices happened more frequently in science lessons. The OECD also created an index named “Enquiry-based science instruction”, which combines nine statements to measure the extent to which science teachers encourage students to be deep learners and the extent to which they are encouraged to enquire about a science problem using scientific methods, including experiments. Regarding the latter, i.e. the inquiry-based instruction index, we used the variable measuring the frequency with which “the teacher explains how <school science> idea can be applied to different phenomena”, because research indicates that this variable indicates a more basic level of scientific enquiry (Jiang & McComas, 2015) and illustrates real-life applications in science lessons. Indeed, findings from the OECD (2016c) reveal that this variable is the only one in the index that is positively associated with students’ achievement. Regarding ability grouping, we used information reported by the principal on “Ability grouping within classes”.

Detailed information regarding the variables used to measure teaching practices and the learning environment in science is given in Tables 6.1 and 6.2.

Our analyses rely on student and principal responses to questionnaires. This approach was followed because the link between classroom teaching practices and students’ achievement is indirect in the sense that students and principals, not teachers, respond to questions about teaching practices in their schools. Moreover, the science teachers that responded to the questionnaire are not linked to the specific students they taught. The information available is relative to the students attending schools where the principals report that teachers expose the students to certain learning experiences and have certain expectations for their learning and achievement.

Table 6.1. Information on the variables used to measure teaching practices and the learning environment in science

Name of the variable	Questions	No of categories	Questionnaire
Teaching practices/strategies			
Teacher-directed science instruction (index based on items from question ST103)	**How often do these things happen in your lessons for this <school science> course?** – the teacher explains scientific ideas;	4	Student
	– a whole class discussion takes place with the teacher;	4	Student
	– the teacher discusses our questions;	4	Student
	– the teacher demonstrates an idea.	4	Student
Inquiry instruction (Item ST098Q06TA)	**The teacher explains how a science idea can be applied to a number of different phenomena**	4	Student
Perceived feedback (index based on items from question ST104)	**How often do these things happen in your lessons for this <school science> course?**		
	– the teacher tells me how I am performing in this course;	4	Student
	– the teacher gives me feedback on my strengths in this <school science> subject;	4	Student
	– the teacher tells me in which areas I can still improve;	4	Student
	– the teacher tells me how I can improve my performance;	4	Student
	– the teacher advises me on how to reach my learning goals.	4	Student
Adaptive instruction (index based on items from question ST107)	**How often do these things happen in your lessons for this <school science> course?**		
	– the teacher adapts the lesson to my class' needs and knowledge;	4	Student
	– the teacher provides individual help when a student has difficulties understanding a topic or task;	4	Student
	– the teacher changes the structure of the lesson on a topic that most students find difficult to understand.	4	Student

Table 6.2. Information on the variables used to measure teaching practices and the learning environment in science (cont.)

Name of the variable	Questions	No of categories	Questionnaire
Teacher support (index based on items from question ST100)	**How often do these things happen in your <school science> lessons?**		
	– the teacher shows an interest in every student's learning;	4	Student
	– the teacher gives extra help when students need it;	4	Student
	– the teacher helps students with their learning;	4	Student
	– the teacher continues teaching until students understand the material;	4	Student
	– the teacher gives students an opportunity to express their opinions.	4	Student
Disciplinary climate (index based on items from question ST097)	**How often do these things happen in your <school science> lessons?**		
	– students do not listen to the teacher;	4	Student
	– there is noise and disorder;	4	Student
	– the teacher has to wait for the students for a long time;	4	Student
	– students cannot work well;	4	Student
	– students do not start working for a long time after the lesson begins.	4	Student
Ability grouping within classes (Item SC042Q02TA)	**What is your school's policy about this for students in <national modal grade for 15-year-olds>?**		
	– students are grouped by ability within their classes.	3	School

7. Teaching practices and achievement: variations across EU MS

This section offers an overview of the variations in teaching practices in science lessons across EU MS, including the frequency of different teaching practices and their relationship with students' achievement. Specifically, univariate statistics[6] are presented, showing the association with each teaching practice and students' science achievement. Its aim is to complement the information available in the OECD PISA reports and to describe differences and similarities within and across EU MS[7].

7.1. Teaching practices in science

Teacher-directed science instruction

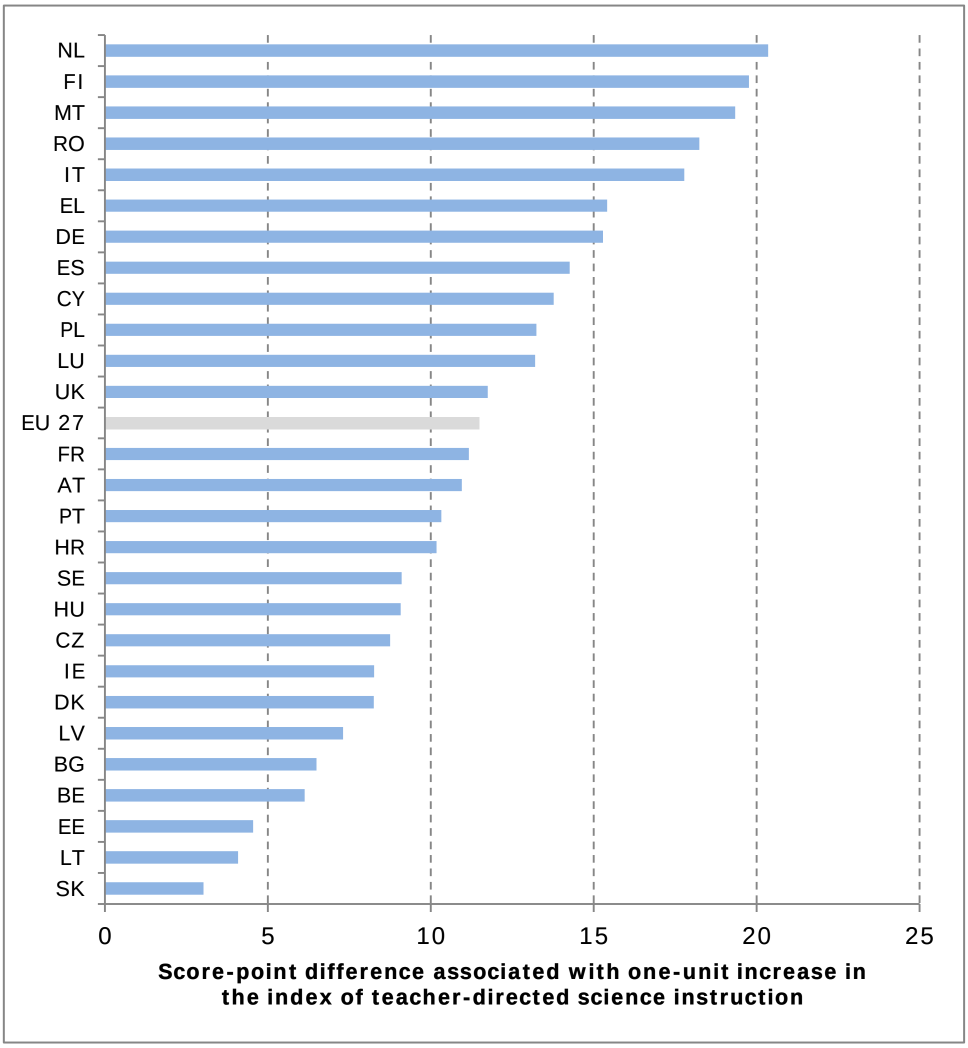
The goal of teacher-directed science instruction is to provide a well-structured, clear and informative lesson on a topic, which usually includes explanations from the teacher, classroom debates and questions from students. To assess the extent to which science teachers' direct student learning in science lessons, a continuous index[8] was constructed by the OECD based on the frequency of four events that happen in students' science lessons. The frequency ranges from "never or almost never" to "every lesson or almost every lesson". Higher values on this index on science instruction indicate more frequent use of these strategies, according to students' reports.

[6] Please note that this section presents only univariate/correlational analyses.
[7] The total number of EU MS may vary according to the index/variable used, as in some EU MS not all the variables were part of the questionnaires.

[8] More information can be found at http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-ii_9789264267510-en#.WR7lVuuGOos

Figure 7.1. Teacher-directed instruction and science performance[9]

Results based on students' reports



Source: Own analysis based on PISA 2015 data. *See also Table 7.1, Annex A.*

Figure 7.1 shows the score-point difference in science associated with a one-unit increase in the index of teacher-directed science instruction.

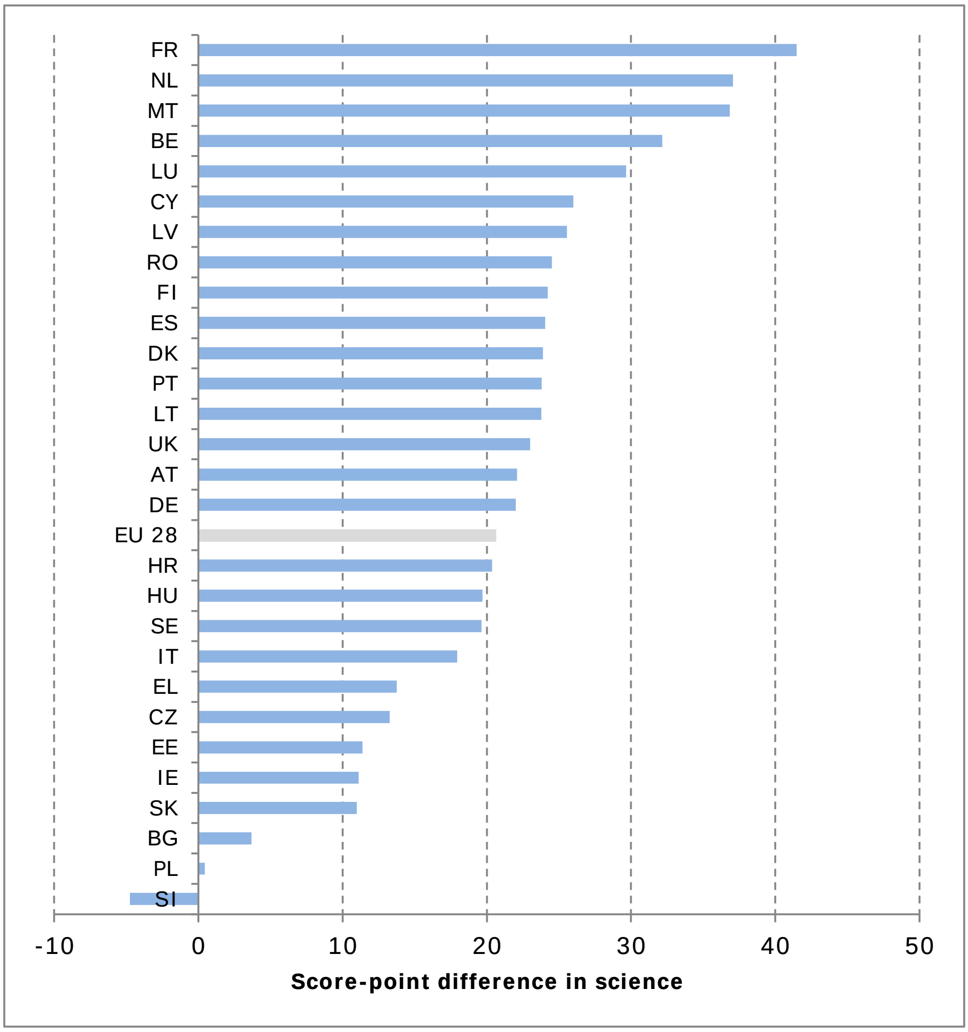
The graph reveals that in all EU MS using teacher-directed instruction more frequently is associated with higher science achievement. The performance differences can amount to as much as 20 score-points, as in the Netherlands, or between 10 and 20 score-points, as in Croatia, Portugal, Austria, France, the United Kingdom, Luxembourg, Poland, Cyprus, Spain, Germany, Greece, Italy, Romania, Malta and Finland, and in the other 12 EU MS the performance differences are smaller than 10 score-points.

[9] All the score-point differences are statistically significant. Countries are ranked in descending order of the score-point difference associated with the index of teacher-directed science instruction. For Slovenia no data are available for this index.

Inquiry instruction

Inquiry instruction refers to students' engagement in experimentation and hands-on activities. We use the variable reported by the students on the frequency with which the "teacher explains how a science idea can be applied to a number of different phenomena". The variable has originally four answer categories ("in all lessons"; "in most lessons"; "in some lessons"; "never or hardly ever"). Following the OECD approach we dichotomise the variable grouping "in all lessons" with "in some lessons" and "in some lessons" with "never or hardly ever".

Figure 7.2. Inquiry instruction and science performance[10]
Results based on students' reports
Measured by "teacher explains how a science idea can be applied" – This happen in "most" or "all" science lessons



Source: Own analysis based on PISA 2015 data. *See also Table 7.2, Annex A.*

Figure 7.2 reveals that in almost all the EU MS there is a positive relationship between a higher frequency of use on inquiry, as measured by the teacher's explanation of how science ideas can be applied, and

[10] Countries are ranked in descending order of the score-point difference in science.

students' science achievement. The differences reach more than 30 points in France, the Netherlands, Malta and Belgium. The exception is Slovenia where a higher frequency of inquiry instruction in the classroom has a negative association with students' achievement in science.

Perceived feedback

Perceived feedback refers to information that students, after being assessed, get from their peers, teachers and parents. This information can modify or reinforce student behaviours and can take several forms, such as praise, surprise, approval or punishment. However, not all types of feedback are equally effective.

The index of perceived feedback[11] was constructed by the OECD from students' reports of their perception of how often their science teachers provide them with regular feedback (categories: "never or almost never"; "some lessons"; "many lessons"; "every lesson or almost every lesson") and inform them or give individual information in their science lessons.

Higher values of this index indicate that the activities happened more frequently in science lessons.

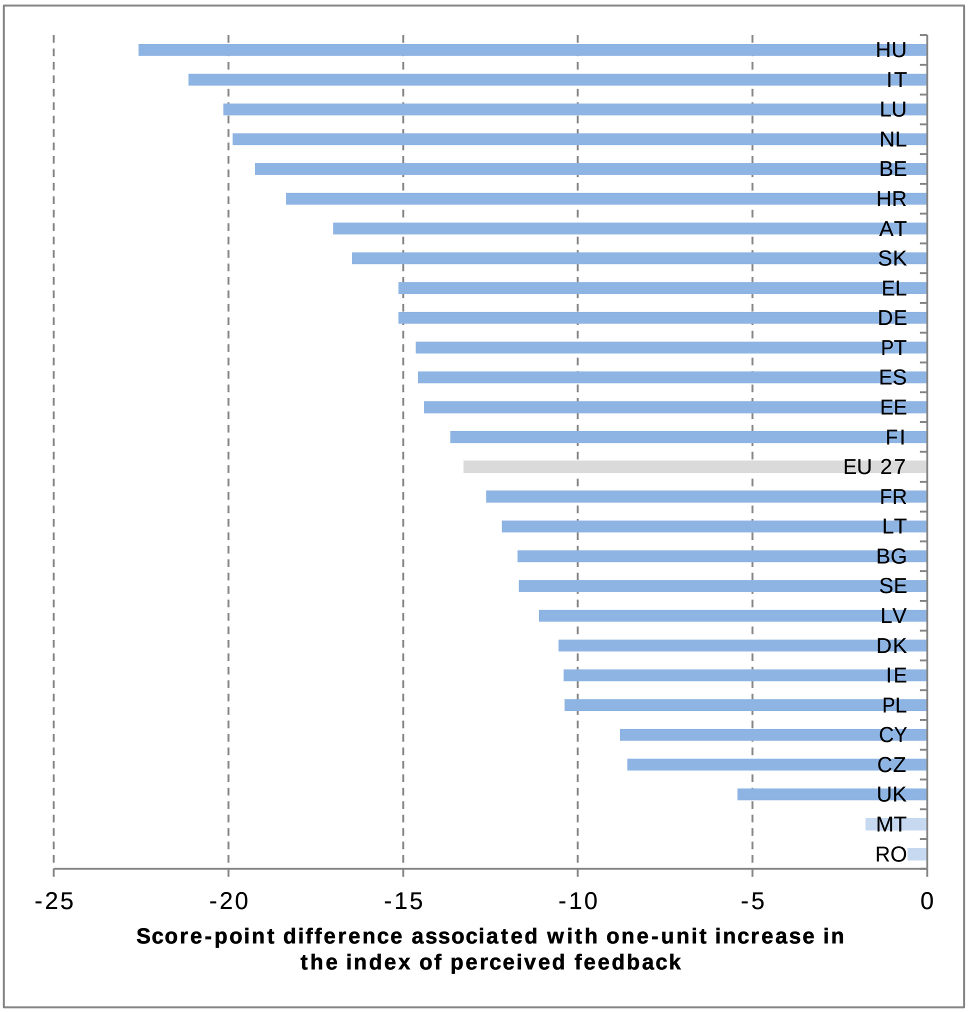
Figure 7.3 shows that all EU MS present a negative relationship of perceived feedback with students' performance in science. The MS with a higher performance difference are Hungary, Italy, Luxembourg, the Netherlands and Belgium. In Malta and Romania the difference is not statistically significant.

These results are in line with those from the OECD (2016c), where a similar analysis was made. In addition, other authors also found that giving feedback can either positively or negatively influence learning and achievement (e.g. Hattie & Timperley, 2007). The negative results may be related to the notion that teachers adjust their feedback to learning goals (Hattie, 2009) and that learners who need more feedback to improve their learning may be lower achieving students.

[11] More information can be found at http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-ii_9789264267510-en#.WR7lVuuGOos

Figure 7.3. Perceived feedback and science performance[12]

Results based on students' reports



Source: Own analysis based on PISA 2015 data. *See also Table7.3, Annex A.*

Adaptive instruction

Adaptive instruction refers to teachers' flexibility in adapting the lessons for students with different knowledge and abilities, including for individual students who are struggling with a topic or task. A continuous index on adaptive instruction[13] that indicates how often science teachers in the school tailor lessons to the students in their classes (including to individual students who are struggling with a task) was constructed by the OECD. It is based on the frequency ("never or almost never"; "some lessons"; "many lessons"; "every lesson or almost every lesson") with which some events happen in students' science lessons.

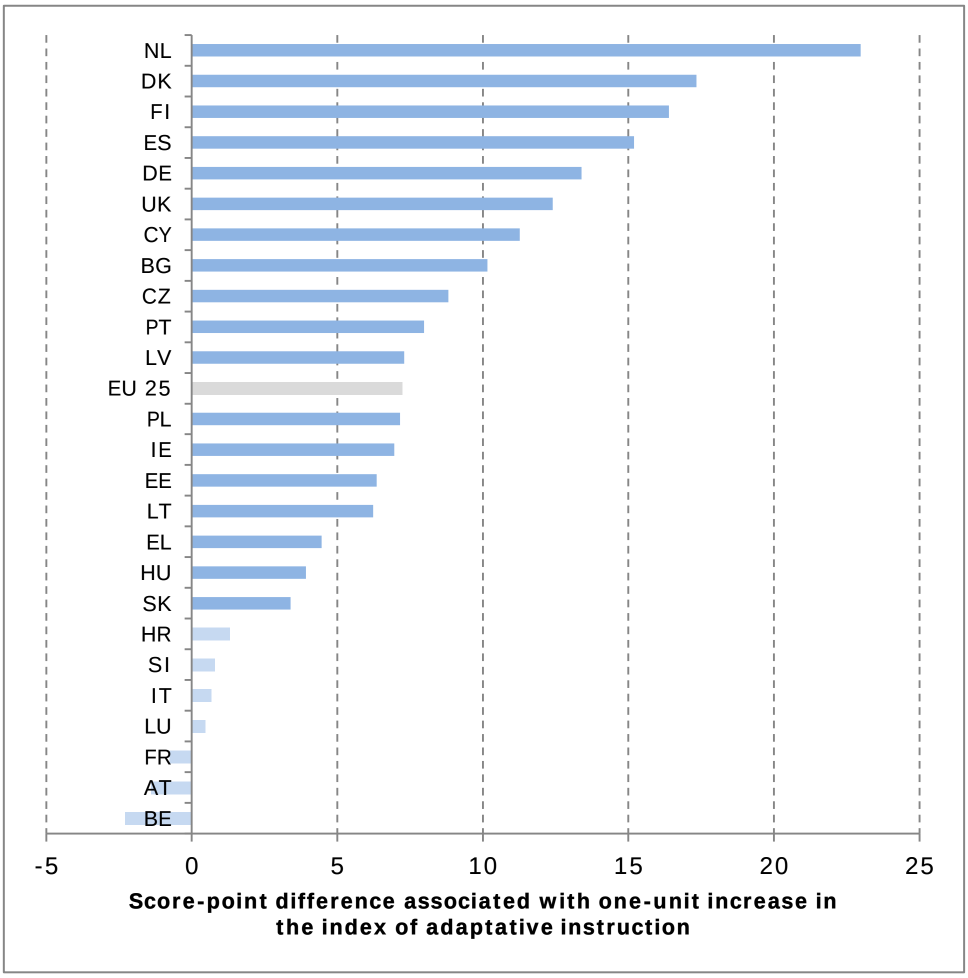
[12] The score-point differences that are statistically significant are presented in a darker blue. Countries are ranked in ascending order of the score-point difference associated with the index of perceived feedback. For Slovenia no data are available for this index.

[13] More information can be found at http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-ii_9789264267510-en#.WR7lVuuGOos.

Higher values in this index indicate that these practices happened more frequently in science lessons.

Figure 7.4. Adaptive instruction and science performance[14]

Results based on students' reports



Source: Own analysis based on PISA 2015 data. *See also Table 7.4, Annex A.*

Figure 7.4 shows that in 18 EU MS a more frequent use of adaptive instruction is positively and significantly associated with students' performance in science. The performance differences ranged from 3 to 23 score-points, with the highest values in the Netherlands, Denmark and Finland. In Croatia, Slovenia, Italy, Luxembourg, France, Austria and Belgium the score-point differences are of a very small magnitude and are not statistically significant. To sum up, the results show that European students do best when teachers provide feedback.

[14] The score-point differences that are statistically significant are presented in a darker blue. Countries are ranked in descending order of the score-point difference associated with the index of perceived feedback. For Malta, Romania and Sweden no data are available for this index.

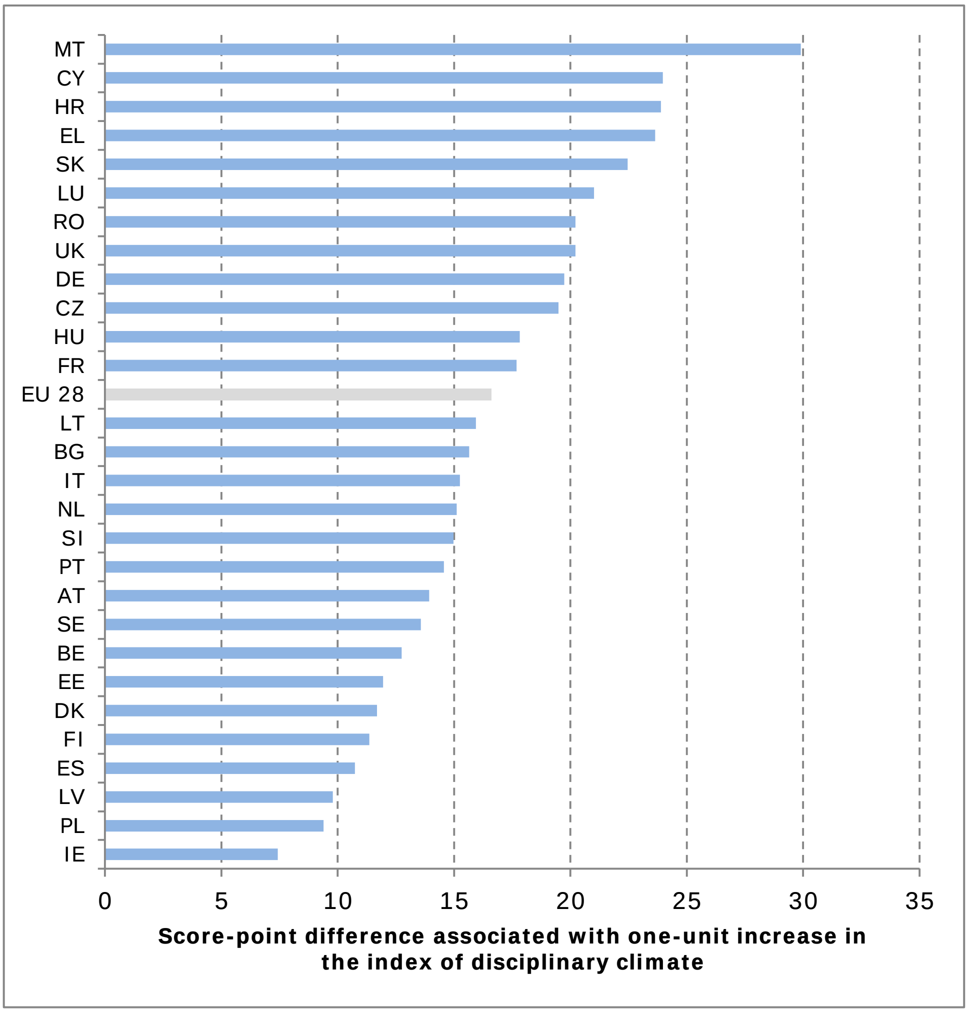
These results are in line with OECD findings, which show that adaptive instruction has a positive impact on student outcomes (Gomendio, 2017).

7.2. Disciplinary climate in science classes

Disciplinary climate refers to the students' behaviour and attitudes within the classroom in terms of interruptions that occur in science lessons (e.g. noise, disorder, students not working well, students taking too much time to quieten down).

Figure 7.5. Disciplinary climate and science performance[15]

Results based on students' reports



Source: Own analysis based on PISA 2015 data. *See also Table 7.5, Annex A.*

[15] The score-point differences that are statistically significant are presented in a darker blue. Countries are ranked in descending order of the score-point difference associated with the index of disciplinary climate.

In PISA 2015, the index of disciplinary climate was constructed by the OECD from students' reports on how often ("every lesson", "most lessons", "some lessons", "never or hardly ever") some interruptions happened in science lessons ("every lesson"; "most lessons"; "some lessons"; "never or hardly ever"). Higher values on the index indicate a more positive disciplinary climate in science lessons.

Figure 7.5 reveals that in all EU MS a better disciplinary climate is associated with higher science achievement. The performance differences can amount to as much as 30 score-points, as in Malta, or between 20 and 30 score-points, as in the United Kingdom, Romania, Luxembourg, Slovakia, Greece, Croatia and Cyprus. In 17 EU MS, the performance difference varies between 10 and 20 score-points. The EU MS with the weakest relationship between disciplinary climate and students' achievement are Ireland, Poland and Latvia.

Disciplinary climate has been shown to have a positive association with achievement (Costa & Araújo, 2015; Gomendio, 2017). This classroom climate characteristic is a strong driver of students' scores in science. In this sense, our results are in line with the literature.

7.3. Teacher support in science classes[16]

Teacher support in PISA refers to the students' answers to items related to teachers' interest and perseverance in making concepts clear to students. The index of teacher support was constructed by the OECD from students' reports on the frequency of how often the teacher helps students with their learning in their science lessons. The frequency ranges from "every lesson" to "never or hardly ever". Higher values on this index indicate more frequent use of these strategies.

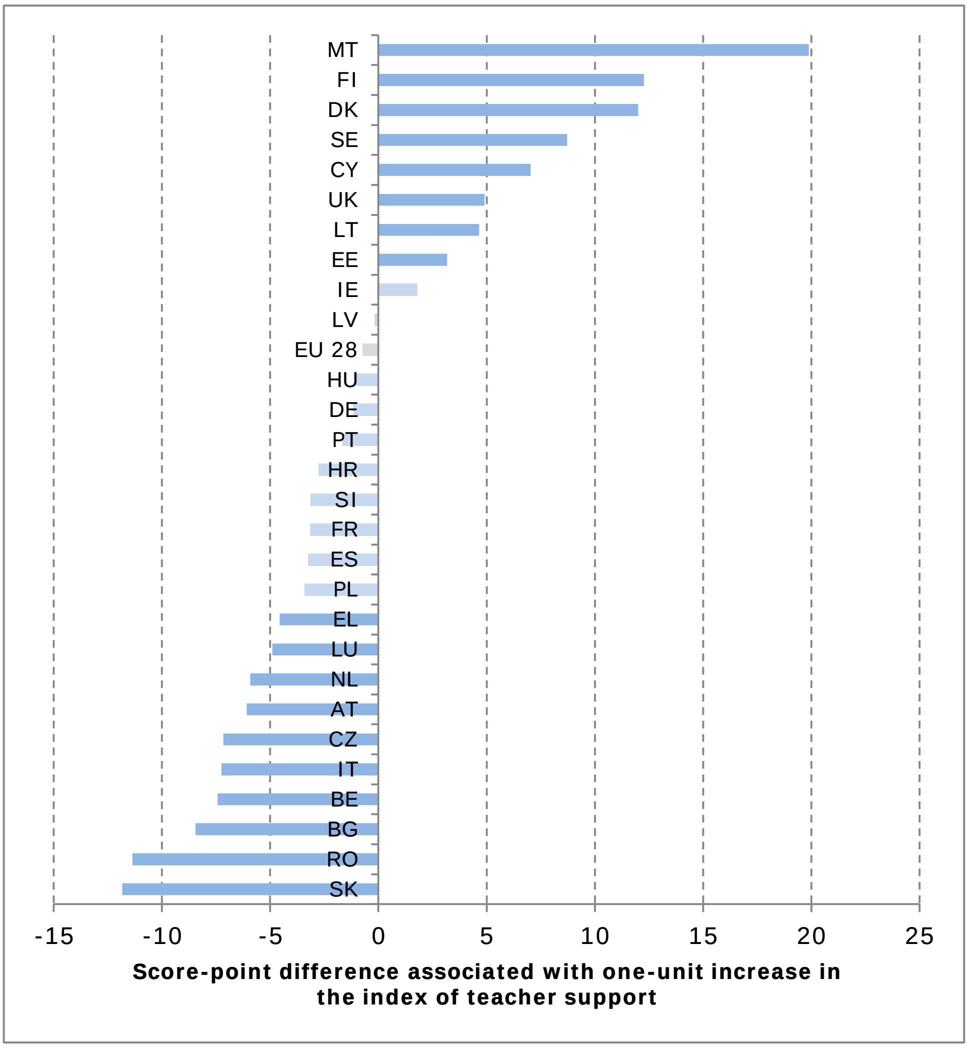
Figure 7.6 shows that in seven EU MS higher teacher support in science lessons is associated with higher science achievement. On the other hand, in 10 EU MS the association between teacher support and students' achievement is negative. The performance differences vary from –12 score-points, in Slovakia, to 20 score-points, in Malta. In 11 EU MS the relationship between teacher support and science skills was not statistically significant. These results are in line with the OECD (2016c) findings, which highlight that teacher support is not always associated with student performance in science. This is true before the socio-economic status of students and schools is accounted for. However, the OECD (2016c) also found that the association between teacher support and student performance becomes positive after accounting for the socio-economic status of students and schools. The literature shows that "disadvantaged students are in greater need of teacher support, and

[16] More information can be found at http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-ii_9789264267510-en#.WR7lVuuGOos

they also tend to score lower in the PISA assessments, so once the analysis accounts for socio-economic status, the association between teacher support and science performance becomes positive in many education systems" (OECD, 2016, V2, p. 96).

Figure 7.6. Teacher support and science performance[17]

Results based on students' reports



Source: Own analysis based on PISA 2015 data. *See also Table 7.6, Annex A.*

[17] The score-point differences that are statistically significant are presented in a darker blue. Countries are ranked in descending order of the score-point difference associated with the index of teacher support.

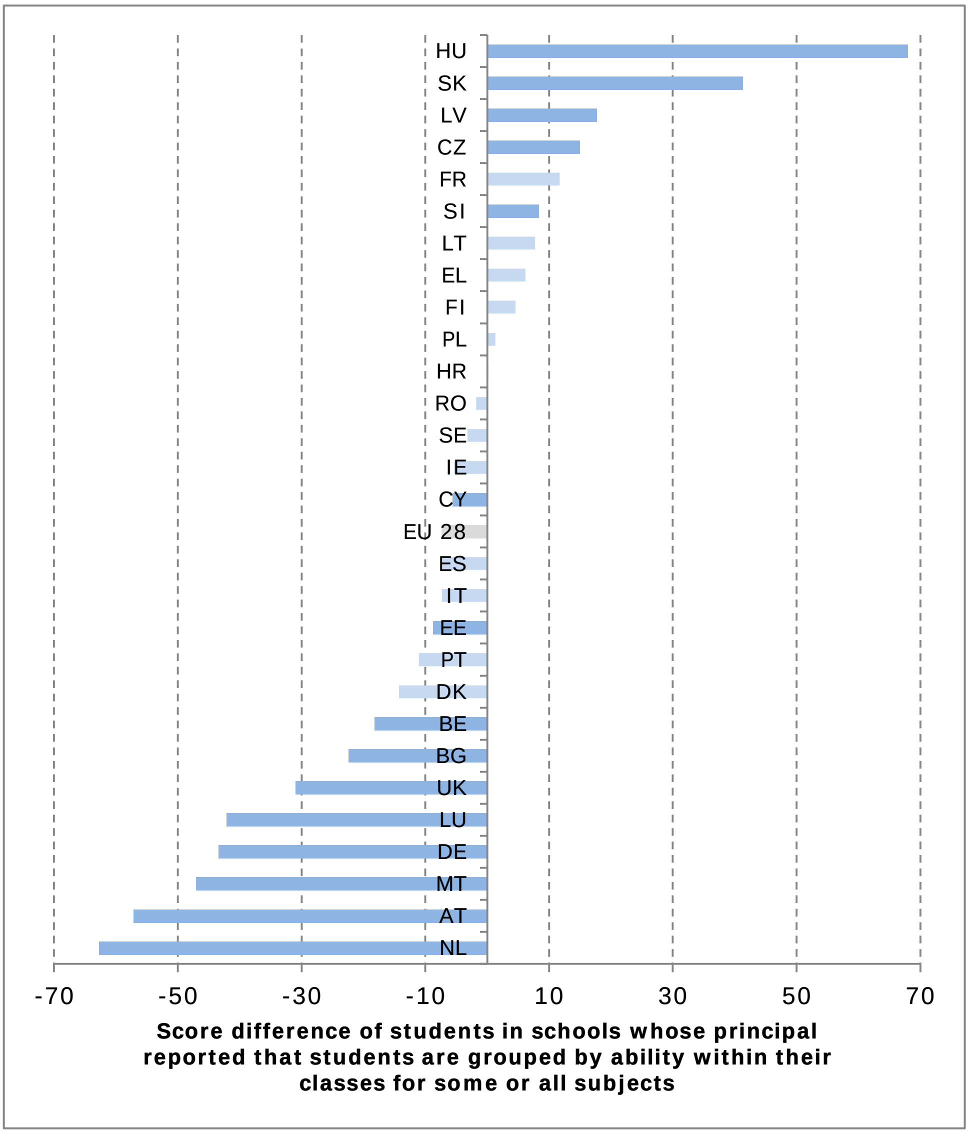
7.4. Ability grouping within classes

Ability grouping within classes was reported by the principals. The Likert scale used distinguishes the following response options: a) for all classes, b) for some classes, c) not for any classes.

Figure 7.7 shows that in 15 EU MS there are statistically significant differences in students' achievement in science for students in schools whose principal reported that students are grouped by ability within their classes for some or all subjects. However, these differences can be associated with either higher or lower achievement. In Hungary, Slovakia, Latvia, the Czech Republic and Slovenia, students in schools whose principals reported that students are grouped by ability within their classes for some or all subjects perform better. On the other hand, in the Netherlands, Austria, Malta, Luxembourg, Germany, Bulgaria, Belgium, Estonia and Cyprus, students in schools whose principals reported that students are grouped by ability within their classes for some or all subjects have lower scores. These results show that in the majority of EU MS there is no association between ability grouping within classes and students' performance in science. In 15 EU MS ability grouping within classes can be either positively or negatively associated with students' performance. Indeed, ability grouping within classrooms may not always have a negative effect because it may reflect adaptive classroom teaching practices that benefit students. In fact, as acknowledged by the OECD PISA Governing Board and as research by Slavin et al. (1990) suggests, ability grouping may better address the needs of individual students and be more beneficial academically if implemented for some subjects.

Figure 7.7. Ability grouping within classes and science performance[18]

Results based on school principals' reports



Source: Own analysis based on PISA 2015 data. *See also Table 7.7, Annex A.*

[18] The score-point differences that are statistically significant are presented in a darker blue. Countries are ranked in descending order of the score difference of students in schools whose principal reported that students are grouped by ability within their classes for some or all subjects.

Highlights – Univariate analysis

- Using teacher-directed instruction more frequently is associated with higher achievement in science.
- All EU MS present a negative relationship of perceived feedback with students' performance in science.
- In 18 EU MS, more frequent use of adaptive instruction is positively and significantly associated with students' performance in science.
- In all EU MS, a better disciplinary climate is associated with higher achievement in science.
- In the majority of EU MS there is a positive relationship between a higher frequency of use of enquiry, as measured by the teacher's explanation of how science ideas can be applied, and students' science achievement.
- In seven EU MS, higher teacher support in the science classroom is associated with higher achievement in science. On the other hand, in 10 EU MS, the association between teacher support and students' achievement is negative.

  In five EU MS, students in schools whose principals reported that students are grouped by ability within their classes for some or all subjects perform better. In contrast, in 10 EU MS, students in schools whose principals reported that students are grouped by ability within their classes for some or for all subjects perform worse.

8. The relationship between teaching practices, the learning environment and students' achievement

This section details the multivariate analyses considering variables at the student level and at the school level, with the outcome measure being the students' PISA score in science. Variables measuring students' socio-economic background and teaching practices in science classrooms are included in the model. As for the school-level variables, the model includes variables related to school characteristics. The analysis is carried out for the EU MS for which PISA 2015 data are available for all variables[19], namely Bulgaria, Croatia, the Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Spain and the United Kingdom.

8.1. Research question

This section aims to answer the following research question: What is the relationship between teaching practices, the learning environment and students' achievement in EU MS[20]? To answer this question we use the data available for the different levels of analysis.

8.2. Methodology

Due to the hierarchical structure of the PISA data in which students are nested in schools we use multilevel modelling (Goldestein, 2003) in order to identify the variation in different teaching practices in the science classroom and their relation with students' achievement. The analysis is presented for the EU participating MS in PISA 2015. The variance components model was applied to the data and the model was then estimated using iterative generalised least squares (IGLS) (Goldestein, 1986). The computational component was generated using MLWin 2.24 software (Rabash, 2009). The bottom-up procedure and the deviance were used to decide which variables to include in the model and multicollinearity was checked.

To provide an answer to our research question, multilevel regression models were used. The variables[21] are included at the student level and at the school level. At the student level, variables measuring teaching practices and learning environment in science were considered, namely

[19] Belgium was excluded from the analysis because of non-existence of one of the variables used for the country level analysis.
[20] For which the data for all variables are available.
[21] More information regarding the variables can be found in Annex B – Table 7.1.

the index of teacher-directed instruction, the inquiry instruction variable, the adaptive instruction index and the perceived feedback index. In addition, we control for a set of socio-economic characteristics to account for the role of other student key background factors (gender, immigration background, economic, social and cultural status (ESCS), class size and students' motivation for achievement). At the school level, the following variables are included in the model: school average of students' socio-economic status, school management (public vs private), school size, proportion of science teachers that are fully certified, and school autonomy (index). The outcome variable considered in our analysis is the students' scores in science.

In PISA, information about teaching and learning is collected mainly through the student and school questionnaires[22], with school principals responding to the latter.

8.3. Results

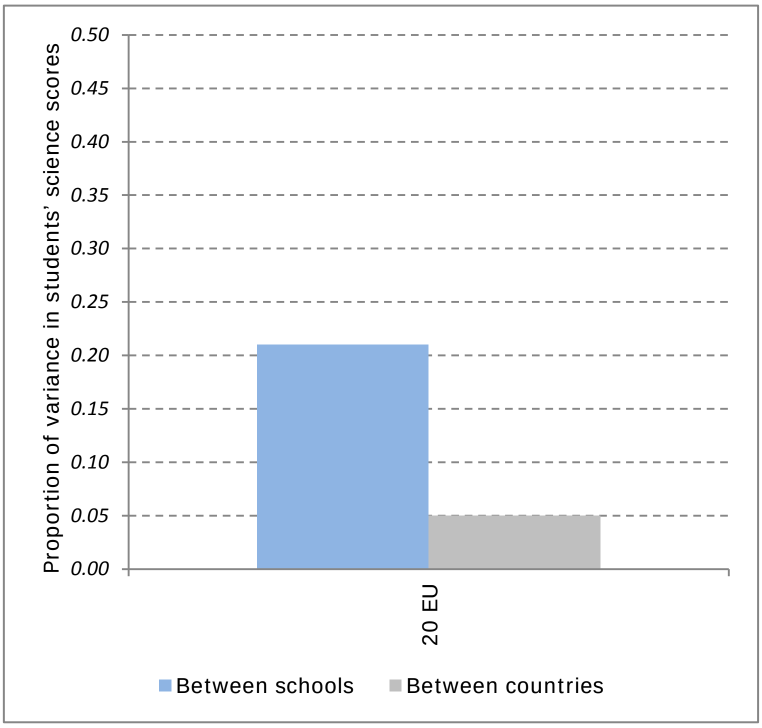
First, we ran a three-level model considering students at level one, schools at level two and countries at level three. The null model was run considering the following 20 EU MS: Bulgaria (BG), Croatia (HR), the Czech Republic (CZ), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), the Netherlands (NL), Poland (PL), Portugal (PT), Slovakia (SK), Spain (ES), and the United Kingdom (UK). This model contains only the dependent variable, i.e. students' scores in science and does not include covariates other than a constant. The null model allows the proportion of variability, calculated using the variances estimated for the errors, between students within schools, between schools within countries and between countries to be obtained. The results (Figure 8.1) show that the proportion of the country-level variance explained by students' achievement in science is 5.2% and that the proportion of the variance as a result of differences between schools is 21%.

After estimating the null model we ran a second model (2), which includes variables measuring teaching practices and learning environment and the control variables at the student and school level. Finally, together with the variables of the second model we included country-level covariates (model 3), namely GDP per capita (euros) by country, as a measure of economic wealth[23], a dichotomous variable indicating the existence or not of external evaluation[24], as a proxy of accountability.

[22] There are also data available on teaching that were collected through the teacher questionnaire, but only five EU MS participated in this optional questionnaire. However, students' achievement and characteristics are not directly linked to the teachers.
[23] Following the approach of Hanushek & Woessmann (2014) we divided the GDP per capita by 1000.
[24] Based on *Education at a Glance* (2015).

These predictors, together with the proportion of fully certified teachers, are used as proxies for teaching quality. These covariates have been used by Hanushek and Woessmann (2014) and have been found to be reliable indicators of cross-country variations, in some cases contributing to boosting students' achievement (Hanushek & Raymond, 2006; Hanushek & Woessmann, 2014; OECD, 2011).

Figure 8.1. Proportion of between-school and between-country variances – 20 EU MS



Source: Own analysis based on PISA 2015 data. *See also Table 8.1, Annex B.*

Having explored the teaching practices and learning environment and the control variables at the student and school levels there was still some unexplained variance that could be attributed to country-level characteristics. As expected, controlling for the country-level predictors led to a large decrease in the country-level unexplained variance from 462 to 279. This corresponds to a decrease of 39.6% of the unexplained variance[25]. This suggests that around 40% of the differences between countries in science achievement is explained by the measures pertaining to a country's economic wealth and school accountability.

More specifically, across the 20 EU MS considered in the analysis, students in countries that have accountability policies, as measured by the existence of external evaluation, score 27 score-points higher in science. The variable measuring a country's economic wealth is not significantly associated with students' performance in science. This means that,

[25] The value of 39.6% is obtained by comparing the random part (constant) for the country level in models 2 and 3, which are presented in Annex B – Table 8.2.

although some literature suggests that differences in cognitive skills are associated with differences in economic growth, this country-level characteristic may not be so important when considering other students and school variables across these 20 EU MS.

Table 8.1. Three -level model for the 20 EU – Association between teaching practices and school learning environment[26] and students' performance in science

Results based on students and school principals' reports

		Statistically significant coefficient	
		Yes	No
Variables measuring teaching practices and school learning environment	Teacher-directed science instruction	X	
	Inquiry – the teacher explains how <school science> idea can be applied	X	
	Perceived feedback	X	
	Adaptive instruction	X	
	Teachers' support in science classes	X	
	Disciplinary climate	X	
	Ability grouping		X
Country-level variables	Economic wealth		X
	Accountability	X	

Source: Own analysis based on PISA 2015 data. *See also Table 8.3, Annex B.*

In addition, we found that all the variables measuring teaching practices and learning environment, except for ability grouping within classes, are statistically significant (Table 8.1). Darker blue cells indicate a positive significant coefficient and lighter blue cells indicate a negative statistically significant coefficient.

[26] Three-level model with the following control variables considered: 1) at the student level, gender, immigration background, economic, social and cultural status (ESCS), class size and students' motivation to achieve; and 2) at the school level, school average of students´ socio-economic status, school management (public vs private), school size, proportion of science teachers fully certified and school autonomy.

To explore the research question more in depth according to specific contexts, we ran a multilevel model for each country. The same two-level model – students and schools – was applied to 16 EU MS[27] (Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Italy, Lithuania, Luxembourg, the Netherlands, Portugal, Slovakia, Spain and United Kingdom). Some countries were excluded from the analysis on account of the non-existence of variance between schools, which precludes the use a multilevel model, namely Latvia, Ireland and Poland.

Table 8.2 presents a summary of the findings on teaching practices and the learning environment that explain variation in students' achievement across the different EU MS. As previously indicated, darker blue cells indicate a positive significant coefficient and lighter blue cells indicate a negative statistically significant coefficient.

The results show that:

- Teacher-directed instruction is positively associated with students' performance in science in 16 EU MS.
- Enquiry instruction, as measured by the variable "the teacher explaining how an idea can be applied", favours students' achievement in science in 14 EU MS. The exceptions are Bulgaria and Estonia.
- Perceived feedback has a negative (and statistically significant) relationship with students' performance in science in all EU MS.
- Adaptive instruction is positively associated with students' achievement in science in all 16 EU MS.
- Teacher support is negatively associated with students' performance in science in 11 EU MS. The EU MS with no association between teacher support and students' achievement are Estonia, Finland, France, Germany and Lithuania.
- A better disciplinary climate is associated with better students' performance in science in all EU MS, except in France.
- Only in the Netherlands is ability grouping in a few lessons (compared with its use in all lessons) associated with higher achievement in science.

[27] Hungary was excluded from the analysis because of the very high percentage of missing values.

Table 8.2. Teaching practices and learning environment and science performance[28]

Results based on students' and school principals' reports

	Teaching practices and learning environment in science						
	Teaching practices / strategies						
	Teacher-directed instruction	Inquiry – the teacher explains <school science> idea can be applied to different phenomena	Perceived feedback	Adaptive instruction	Teachers support in science classes	Disciplinary climate	Ability grouping
Bulgaria							
Croatia							
Czech Republic							
Estonia							
Finland							
France							
Germany							
Greece							
Italy							
Lithuania							
Luxembourg							
Netherlands							
Portugal							
Slovakia							
Spain							
United Kingdom							
EU MS with positive association	16	14	0	16	0	16	0
EU MS with no association	0	2	0	0	5	0	15
EU MS with negative association	0	0	16	0	11	0	1

Source: Own analysis based on PISA 2015 data. *See also Tables 8.4 and 8.5, Annex B.*

[28] Control variables considered: 1) at the student level, gender, immigration background, economic, social and cultural status (ESCS), class size and students' motivation to achievement; and 2) at the school level, school average of students' socio-economic status, school management (public vs private), school size, proportion of science teachers fully certified and school autonomy.

In general, the results[29] also indicate that higher students' motivation to achieve favours students' achievement in science in all 16 EU MS. In terms of other background variables (fixed part), the model shows that in 14 EU MS boys perform better in science than girls. The exceptions are in Finland, where girls tend to perform better than boys in science, and in Lithuania, where no association was found. In addition, the higher the socio-economic status of the students attending a school, the higher their science achievement and, in general, immigrant status is associated with lower achievement.

In terms of school factors, the results reveal that, the higher the average socio-economic status of the students attending a school, the higher their science achievement, and in some EU MS students attending private schools perform better than students attending public schools. The exception is Finland.

[29] See Table 8.4 in Annex B for the model summary on the control variables at the student/classroom level and at the school level and Table 8.5 in Annex B for more detailed information by country.

Highlights – Multivariate analysis

- Teacher-directed instruction is positively associated with students' performance in science in the 16 EU MS.
- Inquiry instruction, as measured by the variable "the teacher explaining how an idea can be applied to different phenomena", is positively associated with students' achievement in science in 14 out of 16 EU MS.
- Perceived feedback has a negative association with students' performance in science in the 16 EU MS.
- Adaptive instruction is positively associated with students' achievement in science in all 16 EU MS.
- Teacher support is negatively associated with students' performance in science in 11 of 16 EU MS.
- A better disciplinary climate is associated with better students' performance in science in 15 out of 16 EU MS.
- Only in one EU MS is using ability grouping in a few lessons (compared with its use in most or all lessons) is associated with higher achievement in science.

Conclusions and discussion

This report on the quality of teaching and learning provides insights into teaching practices that are specific to science teaching, namely teacher-directed teaching and inquiry practices. In particular, we focus on the reported use of different science teaching practices and their relationship with student science achievement. To understand this association, we include other teaching effectiveness dimensions, such as teacher support and disciplinary climate, and we account for student, classroom and school input factors (e.g. gender, socio-economic status, class size and ability grouping) to control for the background and contextual factors that may be related to science learning outcomes. Our analysis uses cross-sectional data from PISA 2015 for the EU participating MS and is based on students' and school principals' answers about the frequency of specific school science activities and related conditions for learning.

The results show that teacher-directed instruction is positively associated with students' performance in science. This is true even when other teaching, learning and individual factors are considered and is in line with the patterns found by the OECD (2016c) and Mayer (2004).

Importantly, we also found a positive relationship between a higher frequency of enquiry-based teaching, as measured by the teacher's explanation of how science ideas can be applied to different phenomena and students' science achievement. This is in contrast with findings from the OECD (2016c). Our measure for enquiry-based teaching illustrates real-life applications and indicates a more basic level of scientific enquiry. On the other hand, OECD findings are based on an index composed of several variables. In this sense, our study adds to existing evidence by showing that a more basic level of enquiry is positively associated with students' achievement.

Our results also suggest that a more frequent use of adaptive instruction, defined as teachers' flexibility in adapting lessons to the students' needs, is positively and significantly associated with students' performance in science. This shows that students from the EU MS considered in our analysis perform better when teachers have the capacity to respond and adapt their practices for individual student needs. Again, this is in accordance with OECD findings.

Our multivariate analysis reveals that a better disciplinary climate is associated with better student performance in science. This finding shows that disciplinary climate is a strong driver of students' performance in science. Other studies also reveal a positive association between a good disciplinary climate and students' achievement (Costa & Araújo, 2015; Gomendio, 2017).

Considering the results for the model with all EU MS and the models for individual countries, one pattern seems clear in relation to teaching practices: teacher-directed instruction, adaptive instruction and disciplinary climate are always positively associated with science achievement. Inquiry-based instruction is overwhelmingly positive and it is not associated with achievement in only two countries. In this sense, these findings suggest that these are the teaching practices that matter most and that these should be considered by stakeholders to improve the quality of teaching and learning in the science classroom.

In what refers to perceived feedback, as measured by the assessment feedback students receive from their teachers, it has a negative association with students' performance in science. This negative association is in line with the findings from the OECD (2016c). Hattie (2009) indicates that these results may be related to the notion that teachers adjust their feedback to students' learning needs. This being the case, low achievers may be the ones who need more feedback to improve their learning. In addition, school climate can also influence the findings in this regard.

In terms of teacher support, our results show that its relationship with student performance in science can be either positive or negative. This depends on the type of association with achievement that we capture, namely univariate association or multivariate association (which includes different teaching practices in the classroom, individual and learning environment characteristics). A negative association was found when other teaching practices, individual and school characteristics are considered. This might be because disadvantaged students are in greater need of teacher support and our analysis considers students with different levels of skills.

To sum up, teacher feedback is always negatively associated with achievement and the relation between teacher support and achievement is also negative in the majority of countries. As mentioned in the previous section, this may be a result of teachers giving more feedback to low achievers.

Ability grouping within classes can be positively or negatively related to students' achievement. This is true in our univariate analysis. On the other hand, this kind of ability grouping does not seem to influence students' scores in science when other factors are considered. The exception is the Netherlands, where a negative association with science performance was found in the multivariate analysis. In this sense, the results show that, when other variables are considered, ability grouping does not have a statistically significant association with students' achievement in every country, with the exception of the Netherlands.

It is also a relevant finding that the variance among the 20 EU MS considered in the analysis is explained by accountability, as measured by the existence of external evaluation. That is, students in countries that have external evaluation score higher in science. These findings extend previous findings by the OECD (2016c) regarding teaching practices and their relation with achievement and by Hanushek and Woessmann (2014) in terms of the positive association between the existence of external exams and achievement. Importantly, it extends their results to a larger number of countries.

In conclusion, this report provides insights about what works well in the science classroom in EU MS, but additional insights within national borders can perhaps offer explanations for students' science achievement that our estimates do not capture. Nevertheless, this information strengthens the evidence base and can be used at the EU level to share knowledge about good practices and to inform policy initiatives that focus on high-quality teaching (European Commission, 2016).

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List of abbreviations and definitions

- EU country abbreviations

Code	Country name
AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	The Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	The Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

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Annexes

Table.7.1 - Score-point difference in science associated with one-unit increase in the index of teacher-directed science instruction[30]

Results based on students' reports

Country	b	b.t
SK	3.03	7.47
LT	4.08	4.11
EE	4.55	4.66
BE	6.13	7.01
BG	6.49	13.12
LV	7.31	5.56
DK	8.25	5.43
IE	8.26	2.69
CZ	8.75	13.26
HU	9.08	7.40
SE	9.11	9.54
HR	10.18	11.43
PT	10.33	5.26
AT	10.96	5.53
FR	11.17	9.20
EU 27	11.49	35.96
UK	11.75	4.29
LU	13.20	3.45
PL	13.24	9.44
CY	13.78	8.59
ES	14.26	7.92
DE	15.28	8.85
EL	15.42	6.98
IT	17.78	7.88
RO	18.25	1.95
MT	19.35	7.78
FI	19.77	5.15
NL	20.36	7.16

[30] All the score-point differences are statistically significant. Countries are ranked in ascending order of the score-point difference associated with the index of teacher-directed science instruction. For SL there is no data available for this index.

Table.7.2 - Score-point difference in science for inquiry instruction - measured by teacher explains how a science idea can be applied.[31]

Results based on students' reports
This happen in "most" or "all" science lessons

Country	Score difference
SI	-4.74
PL	0.45
BG	3.69
SK	10.97
IE	11.12
EE	11.38
CZ	13.26
EL	13.75
IT	17.95
SE	19.64
HU	19.69
HR	20.36
EU 28	20.63
DE	22.01
AT	22.09
UK	23.01
LT	23.78
PT	23.80
DK	23.88
ES	24.04
FI	24.21
RO	24.51
LV	25.55
CY	26.00
LU	29.65
BE	32.17
MT	36.84
NL	37.06

[31] Score point difference between students reporting that teacher explains how a science idea can be applied in "most" or "all" science lessons and students reporting that teacher explains how a science idea can be applied never or almost never in science lessons. Countries are ranked in ascending order of the score-point difference in science.

Table 7.3. Score-point difference in science associated with one-unit increase in the index of perceived feedback[32]

Results based on students' reports

Country	b	b.t
RO	-0.56	-0.25
MT	-1.76	-0.78
UK	-5.43	-3.06
CZ	-8.59	-5.83
CY	-8.79	-6.07
PL	-10.38	-6.18
IE	-10.40	-6.36
DK	-10.55	-5.71
LV	-11.12	-7.03
SE	-11.69	-6.28
BG	-11.73	-6.36
LT	-12.18	-7.62
FR	-12.62	-7.68
EU 27	-13.26	-39.73
FI	-13.65	-9.35
EE	-14.40	-8.55
ES	-14.58	-9.15
PT	-14.64	-9.06
DE	-15.13	-7.47
EL	-15.13	-10.61
SK	-16.46	-9.33
AT	-17.00	-10.25
HR	-18.35	-10.80
BE	-19.24	-11.94
NL	-19.88	-8.71
LU	-20.14	-15.14
IT	-21.14	-12.76
HU	-22.57	-13.11

[32] Countries are ranked in descending order of the score-point difference associated with the index of perceived feedback. For SL there is no data available for this index.

Table 7.4. Score-point difference in science associated with one-unit increase in the index of adaptive instruction[33]

Results based on students' reports

Country	b	b.t
BE	-2.28	-1.58
AT	-1.40	-0.93
FR	-0.75	-0.51
LU	0.46	0.30
IT	0.66	0.39
SI	0.79	0.50
HR	1.31	0.94
SK	3.40	2.21
HU	3.93	2.22
EL	4.46	2.92
LT	6.24	3.91
EE	6.35	4.15
IE	6.96	5.46
PL	7.16	5.12
EU 25	7.22	22.47
LV	7.30	3.92
PT	7.98	5.72
CZ	8.82	5.36
BG	10.16	5.70
CY	11.26	7.25
UK	12.40	6.86
DE	13.39	8.43
ES	15.20	11.00
FI	16.39	10.19
DK	17.34	10.69
NL	22.98	9.91

[33]. Countries are ranked in ascending order of the score-point difference associated with the index of perceived feedback. For *MT, RO, SE* there is no data available for this index.

Table 7.5. Score-point difference associated with one-unit increase in the index of disciplinary climate[34]

Results based on students' reports

Country	b	b.t
IE	7.43	4.48
PL	9.40	5.12
LV	9.79	5.27
ES	10.74	5.86
FI	11.36	5.99
DK	11.69	7.22
EE	11.96	6.29
BE	12.75	9.58
SE	13.57	7.27
AT	13.93	6.50
PT	14.57	7.27
SI	14.98	5.82
NL	15.12	6.44
IT	15.25	9.02
BG	15.66	8.18
LT	15.94	10.94
EU 28	16.58	46.69
FR	17.68	9.20
HU	17.82	8.46
CZ	19.48	11.84
DE	19.74	10.01
UK	20.21	12.31
RO	20.22	8.71
LU	21.02	16.88
SK	22.46	12.37
EL	23.65	10.03
HR	23.89	14.38
CY	23.97	15.65
MT	29.90	17.00

[34] Countries are ranked in ascending order of the score-point difference associated with the index of disciplinary climate.

Table.7.6. - Score-point difference in science associated with one-unit increase in the index of teacher support[35]

Results based on students' reports

Country	b	b.t
SK	-11.84	-6.83
RO	-11.36	-5.51
BG	-8.45	-4.92
BE	-7.43	-4.20
IT	-7.26	-4.40
CZ	-7.17	-4.18
AT	-6.08	-3.16
NL	-5.92	-2.21
LU	-4.90	-3.10
EL	-4.57	-3.01
PL	-3.41	-1.96
ES	-3.25	-1.99
FR	-3.16	-1.84
SI	-3.13	-1.11
HR	-2.77	-1.61
PT	-1.65	-1.01
DE	-1.16	-0.67
HU	-1.05	-0.60
EU 28	-0.73	-2.13
LV	-0.17	-0.09
IE	1.79	1.35
EE	3.17	1.95
LT	4.65	3.82
UK	4.90	2.88
CY	7.03	4.31
SE	8.71	5.33
DK	12.00	6.61
FI	12.27	8.10
MT	19.88	9.33

[35] Countries are ranked in ascending order of the score-point difference associated with the index of teacher support

Figure 7.7. Score difference in science of students in schools whose principal reported that students are grouped by ability within their classes for some or all subjects[36]

Results based on school principals' reports

Country	Score difference
NL	-62.72
AT	-57.12
MT	-47.03
DE	-43.40
LU	-42.14
UK	-30.95
BG	-22.45
BE	-18.24
DK	-14.23
PT	-11.04
EE	-8.77
IT	-7.32
ES	-7.14
EU 28	-7.38
CY	-5.57
IE	-5.34
SE	-3.16
RO	-1.77
HR	0.16
PL	1.30
FI	4.55
EL	6.20
LT	7.75
SI	8.32
FR	11.74
CZ	14.92
LV	17.64
SK	41.30
HU	67.91

[36] Countries are ranked in ascending order of the score difference of students in schools whose principal reported that students are grouped by ability within their classes for some or all subjects.

Annex B

Table. 8.1 – Variables included in the multilevel models

Variables	Code	Questionnaire
STUDENT		
Gender	ST004D01T	Student
SES – Economic, social and cultural status	ESCS	Student
Immigration background	IMMIG	Student
Motivation for achievement (index)	MOTIVAT	Student
Class size	CLSIZE	School
TEACHING PRACTICES AND TEACHING PRACTICES AND LEARNING ENVIRONMENT		
Instructional practices in science		
Teacher-directed science instruction (index)	TDTEACH	Student
Inquiry - The teacher explains <school science> idea can	ST098Q06TA	Student
be applied		Student
Perceived feedback (index)	PERFEED	Student
Adaptive instruction (index)	ADINST	
Teacher quality		
Disciplinary climate in science classes	DISCLISCI	Student
Teacher support in a science classes of students choice	TEACHSUP	Student
Ability grouping within classes	SC042Q02TA	School
SCHOOL		
School average PISA index of economic, social and cultural status		Student
School private or public	SC013Q01TA	School
School size	SCHSIZE	School
Index proportion of science teachers fully certified (index)	PROSTCE	School
Index of school autonomy (index)	SCHAUT	School

Table 8.2. Proportion of between-school and between-country variances – 20 EU

20 EU	Null Model
Fixed Part (constant)	489
Random Part (constant) - Student level	7484
Random Part (constant) - School level	2192
Random Part (constant) - Country level	536
School variance expl. %	21.5
Country variance expl. %	5.2

Table 8.3. Multilevel coefficients for the relationship between Teaching practices and learning environment in science and students' science achievement[37].

	Null Model	Model 2		Model 3	
		Coef.	Std. Error	Coef.	Std. Error
Fixed Part (constant)	489	508		495	
STUDENT					
Gender		**12.3**	1.96	**12.3**	1.95
SES		**16.7**	1.39	**16.8**	1.39
Immigration background		**-21.4**	2.71	**-21.4**	2.7
Motivation for achievement		**11.1**	0.89	**11.1**	0.89
Class size		0.4	0.21	0.4	0.21
TEACHING PRACTICES AND TEACHING PRACTICES AND LEARNING ENVIRONMENT					
Instructional practices in science					
Teacher-directed science instruction (index)		**8.6**	1.02	**8.6**	1.00
Inquiry - The teacher explains <school science> idea can be applied		**-5.2**	0.94	**-5.2**	0.94
Perceived feedback (index)		**-16.8**	1.05	**-16.9**	1.04
Adaptive instruction (index)		**9.3**	0.74	**9.3**	0.74
Teacher quality					
Disciplinary climate in science classes		**9.1**	0.73	**9.1**	0.73
Teacher support in a science classes of students choice		**-4.5**	0.71	**-4.5**	0.72
Ability grouping within classes		**2.0**	1.44	1.9	1.44
SCHOOL					
School average PISA index of economic, social and cultural status		**51.6**	5.46	**51.6**	5.44
School private or public		-4.9	3.7161	-5.0	3.7032
School size		0.0	0.00	0.0	0.00
Index proportion of science teachers fully certified (index)		**11.8**	3.07	**11.9**	3.04
Index of school autonomy (index)		-1.8	5.98	-1.7	5.89
COUNTRY					
Economic wealth				0.0	0.19
Accountability				**27.1**	7.88
Random Part (constant) (School level)	2192	488		486	
Random Part (constant) (Country level)	536	462		279	
Deviance	1595946	998399		998313	

[37] Multilevel regression of students' performance in science. The first model is the null model; model (2) includes including variables measuring teaching practices and learning environment and the control variables at the student and school level; model (3) adds country level covariates. Standard errors in parenthesis . *p*-values: **bold** for *p* < = 0.05.

Table 8.4. Students/classroom and schools characteristics and science performance[38]

Results based on students and school principals' reports

		Control variables at the student/classroom and school levels								
	gender (1 Female)	ESCS	IMMIG (1=native)	Motivation for achievement	Class Size	School public/private (1=public)	School ESCS	School size	Proportion of science teachers fully certified	School autonomy
Bulgaria	Darker blue	Darker blue	Lighter blue	Darker blue		Lighter blue	Darker blue	Darker blue		
Croatia	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			
Czech Republic	Darker blue	Darker blue	Lighter blue	Darker blue	Darker blue	Lighter blue	Darker blue			
Estonia	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			
Finland	Lighter blue	Darker blue	Lighter blue	Darker blue		Darker blue				
France	Darker blue	Darker blue	Lighter blue	Darker blue	Darker blue		Darker blue			
Germany	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			Lighter blue
Greece	Darker blue	Darker blue	Lighter blue	Darker blue		Lighter blue	Darker blue			
Italy	Darker blue	Darker blue	Lighter blue	Darker blue		Lighter blue	Darker blue		Lighter blue	
Lithuania	Darker blue	Darker blue		Darker blue	Darker blue		Darker blue		Darker blue	
Luxembourg	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			
Netherlands	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			
Portugal	Darker blue	Darker blue		Darker blue			Darker blue			
Slovakia	Darker blue	Darker blue	Lighter blue	Darker blue	Darker blue		Darker blue		Darker blue	
Spain	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			
United Kingdom	Darker blue	Darker blue	Lighter blue	Darker blue			Darker blue			Darker blue

[38] Darker blue cells indicate a positive significant coefficient and lighter blue cells indicate a negative statistically significant coefficient.

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country[39]

		Bulgaria		Croatia		Czech Republic	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
	Fixed Part (constant)	**547.1**	40.21	**417.4**	35.94	**463.3**	38.33
STUDENT	*Gender*	**5.9**	2.41	**23.0**	2.89	**17.6**	2.25
	ESCS	**7.4**	1.54	**12.4**	1.62	**17.1**	1.59
	Immigration background	**-33.9**	12.02	**-10.7**	3.66	**-20.0**	5.83
	Motivation for achievement	**4.4**	1.25	**7.4**	1.23	**10.2**	1.22
	Class size	-0.3	0.60	0.8	1.04	1.8	0.58
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**						
	Teacher-directed science instruction (index)	**3.8**	1.18	**7.8**	1.08	**5.3**	1.29
	Inquiry - The teacher explains <school science> idea can be applied	-0.7	1.29	**-3.5**	1.32	**-3.9**	1.19
	Perceived feedback (index)	**-10.1**	1.43	**-14.4**	1.48	**-9.4**	1.48
	Adaptive instruction (index)	**10.8**	1.48	**5.3**	1.08	**10.5**	1.41
	Teacher quality						
	Disciplinary climate in science classes	**5.2**	1.24	**11.6**	1.31	**8.7**	1.14
	Teacher support in a science classes of students choice	**-4.0**	1.33	**-3.1**	1.32	**-9.4**	1.51
	Ability grouping within classes	**-3.2**	4.23	**-2.6**	4.10	0.2	4.00
SCHOOL	*School average PISA index of economic. social and cultural status*	**84.9**	8.00	**70.4**	7.56	**82.9**	5.56
	School private or public	**-41.3**	17.47	**22.4**	15.68	**-23.8**	9.25
	School size	0.0	0.01	0.0	0.01	0.0	0.01
	Index proportion of science teachers fully certified	**2.1**	19.08	**15.1**	11.77	**13.4**	13.07
	Index of school autonomy	**-14.5**	19.01	**38.2**	25.46	**40.4**	29.26

[39] Statistically significant coefficients are presented in bold.

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country (cont.)

		Estonia		Finland		France	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
	Fixed Part (constant)	**549.2**	34.73	**600.9**	27.28	**464.8**	26.21
STUDENT	*Gender*	**15.7**	2.23	**-6.5**	2.36	**20.0**	2.43
	ESCS	**18.7**	1.58	**24.7**	1.78	**16.6**	1.59
	Immigration background	**-18.7**	3.75	**-68.6**	7.85	**-22.9**	3.92
	Motivation for achievement	**13.0**	1.46	**17.1**	1.25	**7.2**	1.29
	Class size	-0.1	0.24	0.6	0.69	**3.0**	0.55
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**						
	Teacher-directed science instruction (index)	**4.7**	1.52	**11.4**	1.59	**7.2**	1.35
	Inquiry - The teacher explains <school science> idea can be applied	-1.1	1.59	**-6.4**	1.56	**-6.5**	1.13
	Perceived feedback (index)	**-19.2**	1.59	**-20.8**	1.36	**-8.3**	1.32
	Adaptive instruction (index)	**11.7**	1.59	**12.6**	1.84	**3.6**	1.43
	Teacher quality						
	Disciplinary climate in science classes	**9.6**	1.63	**5.9**	1.61	**3.2**	1.18
	Teacher support in a science classes of students choice	-1.5	1.69	-0.5	1.78	-1.0	1.47
	Ability grouping within classes	**5.3**	4.10	**-5.4**	4.07	**-7.2**	4.32
SCHOOL	*School average PISA index of economic. social and cultural status*	**44.3**	9.50	**14.9**	6.98	**70.5**	6.91
	School private or public	**-16.2**	11.49	**16.0**	10.07	**2.2**	6.93
	School size	0.0	0.01	0.0	0.01	0.0	0.01
	Index proportion of science teachers fully certified	**9.6**	11.88	**6.9**	11.45	**6.7**	9.14
	Index of school autonomy	**-13.7**	22.33	**9.0**	14.30	**-24.1**	16.91

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country (cont.)

		Germany		Greece		Italy	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
	Fixed Part (constant)	**551.5**	27.69	**528.0**	28.49	**553.3**	29.11
STUDENT	*Gender*	**21.6**	3.26	**12.7**	2.39	**23.3**	2.47
	ESCS	**10.2**	1.76	**12.9**	1.52	**6.5**	1.34
	Immigration background	**-41.5**	4.99	**-18.1**	5.18	**-28.0**	5.15
	Motivation for achievement	**8.6**	1.72	**11.3**	1.49	**3.5**	1.52
	Class size	-0.4	0.69	0.0	0.39	-0.1	0.43
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**						
	Teacher-directed science instruction (index)	**7.6**	1.60	**11.8**	1.42	**14.4**	1.72
	Inquiry - The teacher explains <school science> idea can be applied	**-3.0**	1.45	**-4.2**	1.39	**-3.5**	1.35
	Perceived feedback (index)	**-15.2**	2.03	**-16.4**	1.54	**-18.1**	1.42
	Adaptive instruction (index)	**10.5**	1.78	**6.9**	1.39	**5.7**	1.71
	Teacher quality						
	Disciplinary climate in science classes	**8.2**	1.48	**10.1**	1.60	**5.5**	1.51
	Teacher support in a science classes of students choice	**-3.2**	2.09	**-7.6**	1.36	**-3.5**	1.54
	Ability grouping within classes	**3.8**	5.07	0.3	5.29	**2.2**	4.03
SCHOOL	*School average PISA index of economic. social and cultural status*	**82.3**	8.44	**60.1**	6.82	**71.9**	6.77
	School private or public	**19.7**	14.16	**-43.2**	18.03	**-25.7**	14.83
	School size	0.0	0.01	0.0	0.02	0.0	0.01
	Index proportion of science teachers fully certified	**9.5**	7.97	**-4.2**	11.51	**-24.0**	13.45
	Index of school autonomy	**-79.3**	26.92	**29.9**	29.45	**-22.0**	29.60

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country (cont.)

		Lithuania		Luxembourg		Netherlands	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
	Fixed Part (constant)	**405.2**	35.93	**458.0**	33.12	**345.3**	107.05
STUDENT	*Gender*	**6.1**	2.52	**17.8**	1.95	**10.6**	3.88
	ESCS	**13.1**	1.58	**16.2**	2.35	**7.6**	2.47
	Immigration background	**-6.1**	6.52	**-15.8**	3.03	**-23.4**	9.63
	Motivation for achievement	**13.3**	1.05	**5.9**	1.89	**12.0**	2.56
	Class size	1.0	0.43	1.0	1.01	-0.8	1.57
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**						
	Teacher-directed science instruction (index)	**2.6**	1.27	**11.0**	1.40	**8.8**	2.89
	Inquiry - The teacher explains <school science> idea can be applied	**-5.9**	1.27	**-10.0**	1.51	**-7.2**	2.25
	Perceived feedback (index)	**-13.6**	1.64	**-21.6**	2.66	**-18.1**	2.10
	Adaptive instruction (index)	**9.0**	1.55	**6.0**	1.97	**17.2**	2.44
	Teacher quality						
	Disciplinary climate in science classes	**7.8**	1.27	**11.9**	1.29	**7.2**	2.17
	Teacher support in a science classes of students choice	0.2	1.40	**-4.7**	1.60	**-6.8**	2.39
	Ability grouping within classes	0.0	4.22	**10.2**	7.56	**26.1**	11.26
SCHOOL	*School average PISA index of economic. social and cultural status*	**51.3**	7.13	**59.4**	5.77	**124.6**	21.02
	School private or public	**24.9**	16.74	**-9.3**	9.17	**10.0**	10.12
	School size	0.0	0.01	0.0	0.01	0.0	0.01
	Index proportion of science teachers fully certified	**34.3**	17.03	1.7	9.83	**-5.5**	31.12
	Index of school autonomy	**16.2**	15.94	**-3.1**	16.97	**128.1**	97.87

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country (cont.)

		Portugal		Slovakia		Spain	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
	Fixed Part (constant)	**553.4**	34.73	**429.3**	31.39	**580.6**	18.61
STUDENT	*Gender*	**19.3**	2.92	**16.9**	2.25	**11.7**	2.30
	ESCS	**20.6**	1.74	**11.6**	1.77	**17.4**	1.11
	Immigration background	**-12.3**	6.45	**-43.8**	12.00	**-30.7**	4.21
	Motivation for achievement	**16.0**	2.04	**11.6**	1.37	**15.9**	1.44
	Class size	0.4	0.85	**2.3**	0.61	0.0	0.20
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**						
	Teacher-directed science instruction (index)	**8.0**	1.61	**4.1**	1.20	**14.6**	1.58
	Inquiry - The teacher explains <school science> idea can be applied	**-6.3**	2.03	**-4.0**	1.34	**-9.6**	1.61
	Perceived feedback (index)	**-20.6**	1.83	**-12.8**	1.47	**-19.5**	1.61
	Adaptive instruction (index)	**10.0**	2.05	**8.1**	1.36	**4.8**	1.71
	Teacher quality						
	Disciplinary climate in science classes	**10.8**	1.96	**13.6**	1.91	**9.3**	1.47
	Teacher support in a science classes of students choice	**-4.7**	1.96	**-7.9**	1.08	**-6.7**	1.67
	Ability grouping within classes	**-4.6**	6.71	**-3.3**	3.36	0.5	3.33
SCHOOL	*School average PISA index of economic. social and cultural status*	**33.8**	4.27	**58.7**	6.88	**14.9**	3.54
	School private or public	-1.4	11.00	**2.7**	5.37	**-2.9**	5.29
	School size	0.0	0.00	0.0	0.01	0.0	0.00
	Index proportion of science teachers fully certified	-0.8	14.28	**28.8**	10.81	-1.7	6.82
	Index of school autonomy	**-19.5**	17.08	**16.0**	18.30	**-15.9**	11.51

Table 8.5. Multilevel coefficients for the relationship between teaching practices and learning environment in science and students' science achievement by country (cont.)

		United Kingdom	
		Coef.	Std. Error
	Fixed Part (constant)	**493.7**	24.53
STUDENT	*Gender*	**7.9**	2.46
	ESCS	**17.6**	1.79
	Immigration background	**-18.1**	4.39
	Motivation for achievement	**8.2**	1.40
	Class size	0.3	0.54
TEACHING PRACTICES AND LEARNING ENVIRONMENT	**Instructional practices in science**		
	Teacher-directed science instruction (index)	**8.9**	1.99
	Inquiry - The teacher explains <school science> idea can be applied	**-5.5**	1.68
	Perceived feedback (index)	**-15.6**	1.89
	Adaptive instruction (index)	**13.1**	2.25
	Teacher quality		
	Disciplinary climate in science classes	**12.6**	1.48
	Teacher support in a science classes of students choice	**-5.7**	2.07
	Ability grouping within classes	-0.1	3.47
SCHOOL	*School average PISA index of economic. social and cultural status*	**62.1**	6.60
	School private or public	**-5.8**	8.91
	School size	0.0	0.01
	Index proportion of science teachers fully certified	**11.3**	10.64
	Index of school autonomy	**28.8**	11.55

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