COUNTRY NOTE

Key findings from PISA 2015 for the United States

OECD

Country Note

KEY FINDINGS FROM PISA 2015
FOR THE UNITED STATES

OECD
BETTER POLICIES FOR BETTER LIVES

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ABOUT THIS REPORT

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Executive summary

This report describes the performance of 15-year-olds in the United States in the OECD Programme for International Student Assessment (PISA) and compares it to that in four countries/economies: Canada, Estonia, Germany and Hong Kong (China). The report then examines policies from these four education systems, which were all selected for their high performance and high or improving levels of equity. It concludes with a discussion of science instruction in the United States.

KEY FINDINGS FROM PISA

The United States remains in the middle of the rankings

Among the 35 countries in the OECD, the United States performed around average in science, the major domain of this assessment cycle. Its performance was also around average in reading, but below average in mathematics. There has been no significant change in science and reading performance since the last time they were the major domains (science in 2006 and reading in 2009).

One in five (20%) of 15-year-old students in the United States are low performers, not reaching the PISA baseline Level 2 of science proficiency. This proportion is similar to the OECD average of 21%, but more than twice as high as the proportion of low performers in Estonia, Hong Kong (China), Japan, Macao (China), Singapore and Viet Nam.

At the other end of the performance scale, 9% of students in the United States are top performers, achieving Level 5 or 6, comparable to the average of 8% across the OECD. By contrast, over 15% of 15-year-old students in Japan, Singapore and Chinese Taipei achieve this level of performance.

Attitudes towards science are positive overall

Students in the United States display high levels of epistemic beliefs, or those beliefs that correspond with currently accepted representations of the goal of scientific enquiry and the nature of scientific claims. Over nine in ten 15-year-olds in the United States agree that ideas in science sometimes change, that good answers are based on evidence from many different experiments and that it is good to try experiments more than once to be sure of one's findings.

Some 38% of 15-year-olds in the United States expect to work in a science-related career at age 30. Only 24% of students across the OECD, by contrast, expect to do so. The majority of these students in the United States (22%) expect to become health professionals; 13% science and engineering professionals; 2% ICT professionals; and 1% science-related technicians and associates.

Girls are more likely than boys to expect to become health professionals (35% vs. 9%), but boys are more likely than girls to expect to become science and engineering professionals (20% vs. 6%) and ICT professionals (4% vs. 0.5%).

The influence of socio-economic status on student performance is about average, but equity has improved since 2006

In the United States, 11% of the variation in student performance in science could be attributed to differences in socio-economic status, similar to the average variation in performance observed across the OECD. A one-unit increase in the

PISA index of economic, social, and cultural status (ESCS) in the United States is associated with an increase of 33 score points in the science assessment, which is below the average of 38 score points across the OECD.

Disadvantaged students in the United States were 2.5 times more likely to be low performers than advantaged students. However, disadvantage does not consign students to low performance: 32% of disadvantaged students in the United States were resilient, performing above expectations and among the top quarter of students with the same socio-economic status across all countries and economies in PISA. This proportion has increased by 12 percentage points since 2006.

Equity has improved in the United States since 2006, when socio-economic status accounted for 17% of the variation in student performance in science, and a one-unit increase in the ESCS index was associated with an increase of 46 score points. However, mean performance did not increase over the same period. The increase in equity can be attributed to gains in performance among disadvantaged students, but these were not large enough to significantly increase the country's mean performance. There has been little change in science performance among advantaged students.

Students' science performance is also associated to the socio-economic composition of their schools

In the United States, a 91-point gap in science performance exists between students attending advantaged schools and those attending disadvantaged schools. This is larger than the gaps of less than 70 points observed in Canada and Estonia.

The level of between-school variation in science performance in the United States is below the OECD average, whereas within-school variation is higher than the OECD average. The bulk of variation in performance in the United States is observed among students attending the same schools rather than different schools. This is partly due to the fact that schools sort and track students to a lesser extent in the United States than in other OECD countries.

Time and resources devoted to science differ between schools

Principals in disadvantaged schools in the United States are more likely to report a shortage of human resources than principals in advantaged schools. This may exacerbate disparities in performance related to socio-economic status. There are no significant differences in access to material resources across schools.

Advantaged students receive approximately 50 minutes more of science instruction per week in school than their disadvantaged peers. This is equivalent to 30 hours per year for a school year of 36 weeks, compared to 22 hours on average across OECD countries.

POLICIES TO PROMOTE EQUITY IN EDUCATION

Education systems should ensure that all students are able to access high-quality education and reach their full potential, regardless of their social or economic status. Equity does not come at the expense of high performance: Canada, Estonia, Germany and Hong Kong (China) have all attained high levels of performance with high or improving levels of equity.

Five policy pillars that aim to continuously improve teaching and learning in schools and to promote equity in education have been identified, drawing on the experience of these countries:

1. A clear education strategy to improve performance and equity should be implemented.
2. Rigorous and consistent standards should be applied across all classrooms.
3. Teacher and school leader capacity should be improved.
4. Resources should be distributed equitably across schools – preferentially to those schools and students that need them most.
5. At-risk students and schools should be proactively targeted.

APPROACHES TO SCIENCE EDUCATION IN THE UNITED STATES

Science instruction in the United States has changed over the past few decades. In addition to acquisition of knowledge specific to each field of science, emerging science education underscores the concepts spanning many fields of science and the practices used by scientists and engineers. This is in line with what the PISA science assessment examines: the ability to explain scientific phenomena, to evaluate and design scientific inquiry, and to interpret the data collected by the inquiry. Different instructional approaches need to be considered and introduced to enhance students' learning and their use of scientific knowledge in the real world.

1

What is PISA?

This chapter presents PISA, a triennial survey of 15-year-olds' knowledge and skills in science, reading and mathematics, with a focus on science for PISA 2015. It explains the unique process and features of PISA, how it is delivered and to whom, what is measured and how the results are presented.

"What is important for citizens to know and be able to do?" In response to that question and to the need for internationally comparable evidence on student performance, the Organisation for Economic Co-operation and Development (OECD) launched the triennial survey of 15-year-old students around the world known as the Programme for International Student Assessment (PISA). PISA assesses the extent to which 15-year-old students, near the end of their compulsory education, have acquired key knowledge and skills that are essential for full participation in modern societies. The assessment focuses on the core school subjects of science, reading and mathematics. Students' proficiency in an innovative domain is also assessed (in 2015, this domain is collaborative problem solving). The assessment does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have learned and can apply that knowledge in unfamiliar settings, both in and outside of school. This approach reflects the fact that modern economies reward individuals not for what they know, but for what they can do with what they know.

PISA is an ongoing programme that offers insights for education policy and practice, and that helps monitor trends in students' acquisition of knowledge and skills across countries and in different demographic subgroups within each country. PISA results reveal what is possible in education by showing what students in the highest-performing and most rapidly improving education systems can do. The findings allow policy makers around the world to gauge the knowledge and skills of students in their own countries in comparison with those in other countries, set policy targets against measurable goals achieved by other education systems, and learn from policies and practices applied elsewhere. While PISA cannot identify cause-and-effect relationships between policies/practices and student outcomes, it can show educators, policy makers and the interested public how education systems are similar and different – and what that means for students.

WHAT IS UNIQUE ABOUT PISA?

PISA is different from other international assessments in its:

- **policy orientation**, which links data on student learning outcomes with data on students' backgrounds and attitudes towards learning, and on key factors that shape their learning, in and outside of school, in order to highlight differences in performance and identify the characteristics of students, schools and education systems that perform well
- **innovative concept of "literacy"**, which refers to students' capacity to apply knowledge and skills in key subjects, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations
- **relevance to lifelong learning**, as PISA asks students to report on their motivation to learn, their beliefs about themselves, and their learning strategies
- **regularity**, which enables countries to monitor their progress in meeting key learning objectives
- **breadth of coverage**, which, in PISA 2015, encompasses the 35 OECD countries and 37 partner countries and economies.

Box 1.1 PISA's contributions to the Sustainable Development Goals

The Sustainable Development Goals (SDGs) were adopted by the United Nations in September 2015. Goal 4 of the SDGs seeks to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". More specific targets and indicators spell out what countries need to deliver by 2030. Goal 4 differs from the Millennium Development Goals (MDGs) on education, which were in place between 2000 and 2015, in the following two ways:

- Goal 4 is truly global. The SDGs establish a universal agenda; they do not differentiate between rich and poor countries. Every single country is challenged to achieve the SDGs.
- Goal 4 puts the quality of education and learning outcomes front and centre. Access, participation and enrolment, which were the main focus of the MDG agenda, are still important, and the world is still far from providing equitable access to high-quality education for all. But participation in education is not an end in itself; what matters for people and economies are the skills acquired through education. It is the competencies and character qualities that are developed through schooling, rather than the qualifications and credentials gained, that make people successful and resilient in their professional and personal lives. They are also key in determining individual well-being and the prosperity of societies.

In sum, Goal 4 requires education systems to monitor the actual learning outcomes of their young people. PISA, which already provides measurement tools to this end, is committed to improving, expanding and enriching its assessment tools. For example, PISA 2015 assesses the performance in science, reading and mathematics of 15-year-old students in more than 70 high- and middle-income countries. PISA offers a comparable and robust measure of progress so that all countries, regardless of their starting point, can clearly see where they are on the path towards the internationally agreed targets of quality and equity in education.

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Through participation in PISA, countries can also build their capacity to develop relevant data. While most countries that have participated in PISA already have adequate systems in place, that isn't true for many low-income countries. To this end, the OECD PISA for Development initiative not only aims to expand the coverage of the international assessment to include more middle- and low-income countries, but it also offers these countries assistance in building their national assessment and data-collection systems. PISA is also expanding its assessment domains to include other skills relevant to Goal 4. In 2015, for example, PISA assesses 15-year-old students' ability to solve problem collaboratively.

Other OECD data, such as those derived from the Survey of Adult Skills (a product of the OECD Programme for the International Assessment of Adult Competencies [PIAAC]) and the OECD Teaching and Learning International Survey (TALIS), provide a solid evidence base for monitoring education systems. OECD analyses promote peer learning as countries can compare their experiences in implementing policies. Together, OECD indicators, statistics and analyses can be seen as a model of how progress towards the SDG education goal can be measured and reported.

Source: OECD (2016a), *Education at a Glance 2016: OECD Indicators*, OECD Publishing, Paris, http://dx.doi.org/10.1787/eag-2016-en.

WHICH COUNTRIES AND ECONOMIES PARTICIPATE IN PISA?

PISA is now used as an assessment tool in many regions around the world. It was implemented in 43 countries and economies in the first assessment (32 in 2000 and 11 in 2002), 41 in the second assessment (2003), 57 in the third assessment (2006), 75 in the fourth assessment (65 in 2009 and 10 in 2010) and 65 in the fifth assessment. So far, 72 countries and economies have participated in PISA 2015.

■ Figure 1.1 ■

Map of PISA countries and economies

OECD countries

Australia
Austria
Belgium
Canada
Chile
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Japan
Korea
Latvia
Luxembourg
Mexico
The Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

Partner countries and economies in PISA 2015

Albania
Algeria
Argentina
Brazil
B-S-J-G (China)*
Bulgaria
Colombia
Costa Rica
Croatia
Cyprus[1]
Dominican Republic
Former Yugoslav Republic of Macedonia
Georgia
Hong Kong (China)
Indonesia
Jordan
Kazakhstan
Kosovo
Lebanon
Lithuania
Macao (China)
Malaysia
Malta
Moldova
Montenegro
Peru
Qatar
Romania
Russian Federation
Singapore
Chinese Taipei
Thailand
Trinidad and Tobago
Tunisia
United Arab Emirates
Uruguay
Viet Nam

Partner countries and economies in previous cycles

Azerbaijan
Himachal Pradesh-India
Kyrgyzstan
Liechtenstein
Mauritius
Miranda-Venezuela
Panama
Serbia
Tamil Nadu-India

* B-S-J-G (China) refers to the four PISA participating China provinces: Beijing, Shanghai, Jiangsu, Guangdong.

1. 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.

In addition to all OECD countries, the survey has been or is being conducted in:

- **East, South and Southeast Asia**: Beijing, Shanghai, Jiangsu and Guangdong (China), Hong Kong (China), Indonesia, Macao (China), Malaysia, Singapore, Chinese Taipei, Thailand and Viet Nam.
- **Central, Mediterranean and Eastern Europe, and Central Asia**: Albania, Bulgaria, Croatia, Georgia, Kazakhstan, Kosovo, Lebanon, Lithuania, the Former Yugoslav Republic of Macedonia, Malta, Moldova, Montenegro, Romania and the Russian Federation.
- **The Middle East**: Jordan, Qatar and the United Arab Emirates.
- **Central and South America**: Argentina, Brazil, Colombia, Costa Rica, Dominican Republic, Peru, Trinidad and Tobago, and Uruguay.
- **Africa**: Algeria and Tunisia.

WHAT DOES THE TEST MEASURE?

In each round of PISA, one of the core domains is tested in detail, taking up nearly half of the total testing time. The major domain in 2015 was science, as it was in 2006. Reading was the major domain in 2000 and 2009, and mathematics was the major domain in 2003 and 2012. With this alternating schedule of major domains, a thorough analysis of achievement in each of the three core areas is presented every nine years; an analysis of trends is offered every three years.

The *PISA 2015 Assessment and Analytical Framework* (OECD, 2016b) presents definitions and more detailed descriptions of the domains assessed in PISA 2015:

- **Science literacy** 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 enquiry, and interpret data and evidence scientifically.
- **Reading literacy** is defined as students' ability to understand, use, reflect on and engage with written texts in order to achieve one's goals, develop one's knowledge and potential, and participate in society.
- **Mathematical literacy** is defined as students' capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals in recognising the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens.

Box 1.2 **Key features of PISA 2015**

The content

- The PISA 2015 survey focused on science, with reading, mathematics and collaborative problem solving as minor areas of assessment. PISA 2015 also included an assessment of young people's financial literacy, which was optional for countries and economies.

The students

- Approximately 540 000 students completed the assessment in 2015, representing about 29 million 15-year-olds in the schools of the 72 participating countries and economies.

The assessment

- Computer-based tests were used, with assessments lasting a total of two hours for each student.
- Test items were a mixture of multiple-choice questions and questions requiring students to construct their own responses. The items were organised in groups based on a passage setting out a real-life situation. About 810 minutes of test items for science, reading, mathematics and collaborative problem solving were covered, with different students taking different combinations of test items.
- Students also answered a background questionnaire, which took 35 minutes to complete. The questionnaire sought information about the students themselves, their homes, and their school and learning experiences. School principals completed a questionnaire that covered the school system and the learning environment. For additional information, some countries/economies decided to distribute a questionnaire to teachers. It was the first time that this optional teacher questionnaire was offered to PISA-participating countries/economies.

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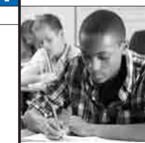

In some countries/economies, optional questionnaires were distributed to parents, who were asked to provide information on their perceptions of and involvement in their child's school, their support for learning in the home, and their child's career expectations, particularly in science. Countries could choose two other optional questionnaires for students: one asked students about their familiarity with and use of information and communications technology (ICT); and the second sought information about students' education to date, including any interruptions in their schooling, and whether and how they are preparing for a future career.

HOW IS THE ASSESSMENT CONDUCTED?

For the first time, PISA 2015 delivered the assessment of all subjects via computer. Paper-based assessments were provided for countries that chose not to test their students by computer, but the paper-based assessment was limited to questions that could measure trends in science, reading and mathematics performance.[1] New questions were developed for the computer-based assessment only. A field trial was used to study the effect of the change in how the assessment was delivered. Data were collected and analysed to establish equivalence between the computer- and paper-based assessments.

The 2015 computer-based assessment was designed as a two-hour test. Each test form allocated to students comprised four 30-minute clusters of test material. This test design included six clusters from each of the domains of science, reading and mathematics to measure trends. For the major subject of science, an additional six clusters of items were developed to reflect the new features of the 2015 framework. In addition, three clusters of collaborative problem-solving items were developed for the countries that decided to participate in that assessment.[2] There were 66 different test forms. Students spent one hour on the science assessment (one cluster each of trends and new science items) plus one hour on one or two other subjects – reading, mathematics or collaborative problem solving. For the countries/economies that chose not to participate in the collaborative problem-solving assessment, 36 test forms were prepared.

Countries that chose paper-based delivery for the main survey measured student performance with 30 pencil-and-paper forms containing trend items from two of the three core PISA domains.

Each test form was completed by a sufficient number of students, allowing for estimations of proficiency on all items by students in each country/economy and in relevant subgroups within a country/economy (such as boys and girls, and students from different social and economic backgrounds).

The assessment of financial literacy was offered as an option in PISA 2015 based on the same framework as the one developed for PISA 2012.[3] The financial literacy assessment lasted one hour and comprised two clusters distributed to a subsample of students in combination with the science, mathematics and reading assessments.

To gather contextual information, PISA 2015 asked students and the principal of their school to respond to questionnaires. The student questionnaire took about 35 minutes to complete; the questionnaire for principals took about 45 minutes to complete. The responses to the questionnaires were analysed with the assessment results to provide both a broader and more nuanced picture of student, school and system performance. The *PISA 2015 Assessment and Analytical Framework* (OECD, 2016b) presents the questionnaire framework in detail. The questionnaires from all assessments since PISA's inception are available on the PISA website: *www.pisa.oecd.org*.

The questionnaires seek information about:

- students and their family backgrounds, including their economic, social and cultural capital
- 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 science activities in class
- aspects of learning, including students' interest, motivation and engagement.

Four additional questionnaires were offered as options:

- **A computer familiarity questionnaire**, focusing on the availability and use of information and communications technology (ICT) and on students' ability to carry out computer tasks and their attitudes towards computer use.
- **An educational career questionnaire**, which collects additional information on interruptions in schooling, on preparation for students' future careers, and on support with science learning.
- **A parent questionnaire**, focusing on parents' perceptions of and involvement in their child's school, their support for learning at home, school choice, their child's career expectations, and their background (immigrant/non-immigrant).
- **A teacher questionnaire**, which is new to PISA, will help establish the context for students' test results. In PISA 2015, science teachers were asked to describe their teaching practices through a parallel questionnaire that also focuses on teacher-directed teaching and learning activities in science lessons, and a selected set of enquiry-based activities. The teacher questionnaire asked about the content of the school's science curriculum and how it is communicated to parents too.

The contextual information collected through the student, school and optional questionnaires are complemented by system-level data. Indicators describing the general structure of the education systems, such as expenditure on education, stratification, assessments and examinations, appraisals of teachers and school leaders, instruction time, teachers' salaries, actual teaching time and teacher training are routinely developed and applied by the OECD (e.g. in the annual OECD publication, *Education at a Glance*). For PISA 2015, these data are extracted from *Education at a Glance 2016* (OECD, 2016a), *Education at a Glance 2015* (OECD, 2015) and *Education at a Glance 2014* (OECD, 2014) for the countries that participate in the annual OECD data collection that is administered through the OECD Indicators for Education Systems (INES) Network. For other countries and economies, a special system-level data collection was conducted in collaboration with PISA Governing Board members and National Project Managers.

WHO ARE THE PISA STUDENTS?

Differences between countries in the nature and extent of pre-primary education and care, in the age at entry into formal schooling, in the structure of the education system, and in the prevalence of grade repetition mean that school grade levels are often not good indicators of where students are in their cognitive development. To better compare student performance internationally, PISA targets students of a specific age. PISA students are aged between 15 years 3 months and 16 years 2 months at the time of the assessment, and have completed at least 6 years of formal schooling. They can be enrolled in any type of institution, participate in full-time or part-time education, in academic or vocational programmes, and attend public or private schools or foreign schools within the country. (For an operational definition of this target population, see Annex A2 in OECD [2016c].) Using this age across countries and over time allows PISA to compare consistently the knowledge and skills of individuals born in the same year who are still in school at age 15, despite the diversity of their education histories in and outside of school.

The population of PISA-participating students is defined by strict technical standards, as are the students who are excluded from participating (see Annex A2 in OECD [2016c]). The overall exclusion rate within a country was required to be below 5% to ensure that, under reasonable assumptions, any distortions in national mean scores would remain within plus or minus 5 score points, i.e. typically within the order of magnitude of 2 standard errors of sampling. Exclusion could take place either through the schools that participated or the students who participated within schools (see Annex A2 in OECD [2016c], Tables A2.1 and A2.2).

There are several reasons why a school or a student could be excluded from PISA. Schools might be excluded because they are situated in remote regions and are inaccessible, because they are very small, or because of organisational or operational factors that precluded participation. Students might be excluded because of intellectual disability or limited proficiency in the language of the assessment.

In 30 out of 72 countries and economies that participated in PISA 2015, the percentage of school-level exclusions amounted to less than 1%; it was 4.1% or less in all countries and economies. When the exclusion of students who met the internationally established exclusion criteria is also taken into account, the exclusion rates increase slightly. However, the overall exclusion rate remains below 2% in 29 participating countries and economies, below 5% in 60 participating countries/economies, and below 7% in all countries/economies except the United Kingdom, Luxembourg (both 8.2%) and Canada (7.5%). In 13 out of the 35 OECD countries, the percentage of school-level exclusions amounted to less than 1% and was less than 3% in 30 OECD countries. When student exclusions within schools are also taken into account, there were 7 OECD countries below 2% and 25 OECD countries below 5%. For more detailed information about school and student exclusion from PISA 2015, see Annex A2 in OECD (2016c).

WHAT KINDS OF RESULTS DOES PISA PROVIDE?

Combined with the information gathered through the tests and the various questionnaires, the PISA assessment provides three main types of outcomes:

- basic indicators that provide a baseline profile of the knowledge and skills of students
- indicators derived from the questionnaires that show how such skills relate to various demographic, social, economic and education variables
- indicators on trends that show changes in outcomes and distributions, and in relationships between student-level, school-level and system-level background variables and outcomes.

WHERE CAN YOU FIND THE RESULTS?

Five volumes present the results from PISA 2015:

- *Volume I: Excellence and Equity in Education* (OECD, 2016c) discusses student performance in science and examines how that performance has changed over previous PISA assessments. This volume examines student engagement with science and attitudes towards science, including students' expectations of working in a science-related career later on. It also provides an overview of student performance in reading and mathematics, and describes the evolution of performance in these subjects over previous PISA assessments. The volume also defines equity in education and examines inclusiveness and fairness in education, with a focus on the socio-economic status of students and schools, and how immigrant background is related to students' performance in PISA and their attitudes towards science. It concludes by discussing what the PISA results imply for policy, and highlighting the policy-reform experience of some countries that have improved during their participation in PISA.
- *Volume II: Policies and Practices for Successful Schools* (OECD, 2016d) examines how student performance is associated with various characteristics of individual schools and concerned school systems. This volume first focuses on science, describing the school resources devoted to science and how science is taught in schools. It discusses how both of these are related to student performance in science, students' epistemic beliefs and students' expectations of pursuing a career in science. The volume then analyses schools and school systems and their relationship with education outcomes more generally, covering the learning environment in school, school governance, student selection and grouping policies, and the human, financial, educational and time resources allocated to education. Trends in these indicators between 2006 and 2015 are examined when comparable data are available.
- *Volume III: Students' Well-Being* describes how well adolescent students are learning and living. This volume analyses a broad set of indicators that collectively paint a picture of the home and school environments of 15-year-old students, the way students communicate with family and friends, how and how often they use the Internet, their physical activities and eating habits, their aspirations for future education, their motivation for school work and their overall satisfaction with life.
- *Volume IV: Students' Financial Literacy* examines 15-year-old students' understanding about money matters in the 15 countries and economies that participated in this optional assessment. The volume explores how the financial literacy of 15-year-old students is associated with their competencies in science, reading and mathematics, with their socio-economic status, and with their previous experiences with money. The volume also offers an overview of financial education in schools in the participating countries and economies, and provides case studies.
- *Volume V: Collaborative Problem Solving* examines students' ability to work with two or more people to try to solve a problem. The volume provides the rationale for assessing this particular skill and describes performance within and across countries. In addition, the volume highlights the relative strengths and weaknesses of each school system and examines how they are related to individual student characteristics, such as gender, immigrant background and socio-economic status. The volume also explores the role of education in building young people's skills in solving problems collaboratively.

Volumes I and II are published in December 2016. Volumes III, IV and V will be published in 2017.

The frameworks for assessing science, reading and mathematics in 2015 are described in *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematics and Financial Literacy* (OECD, 2016b). They are also summarised in *PISA 2015 Results (Volume I): Excellence and Equity in Education* (OECD, 2016c).

Technical annexes at the end of *PISA 2015 Results (Volume I)* (OECD, 2016c) and *(Volume II)* (OECD, 2016d) describe how questionnaire indices were constructed, and discuss sampling issues, quality-assurance procedures, and the process

followed for developing the assessment instruments. Many of the issues covered in the technical annexes are elaborated in greater detail in the *PISA 2015 Technical Report* (OECD, forthcoming).

All data tables referred to in the analyses are included in Annex B1 of *PISA 2015 Results (Volume I)* (OECD, 2016c), and a set of additional data tables is available on line (*www.pisa.oecd.org*). A Reader's Guide is also provided in each volume to aid in interpreting the tables and figures that accompany the report. Data from regions within the participating countries are included in Annex B2 of *PISA 2015 Results (Volume I)* (OECD, 2016c).

Notes

1. The paper-based form was used in 15 countries/economies including Albania, Algeria, Argentina, Georgia, Indonesia, Jordan, Kazakhstan, Kosovo, Lebanon, the Former Yugoslav Republic of Macedonia (FYROM), Malta, Moldova, Romania, Trinidad and Tobago, and Viet Nam, as well as in Puerto Rico, an unincorporated territory of the United States.

2. The collaborative problem solving assessment was not conducted in the countries/economies that delivered the PISA 2015 assessment on paper, nor was it conducted in the Dominican Republic, Ireland, Poland, Qatar or Switzerland.

3. The financial literacy assessment was conducted in Australia, Belgium (Flemish Community only), Beijing-Shanghai-Jiangsu-Guangdong (B-S-J-G [China]), Brazil, Canada, Chile, Italy, Lithuania, the Netherlands, Peru, Poland, the Russian Federation, the Slovak Republic, Spain and the United States.

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2

Viewing education performance and equity in the United States through the prism of PISA 2015

This chapter compares the United States with education systems that show high or improving levels of performance and equity in education in PISA 2015, namely Canada, Estonia, Germany and Hong Kong (China). It provides the context for subsequent chapters, which examine equity policies successfully implemented in these countries and innovative assessment frameworks and interventions designed to improve science education.

PISA consistently shows that performance and equity in education opportunities and outcomes are not mutually exclusive. The most successful education systems are those that combine high levels of achievement and high levels of equity.

Achievement in science, the major domain of PISA 2015, is a measure of the capacity of individuals and countries to confront some of the most complex challenges that humanity faces today, from climate change to intercultural communication and managing technological risks. In countries with high levels of achievement in science, most students – not only those who choose to pursue scientific careers – have a basic understanding of science that will help them become informed citizens in a world shaped by science and technological progress.

Equity in education means that opportunities to acquire these skills should be independent of students' backgrounds. Ensuring that schooling outcomes reflect the abilities, will and effort of students, rather than their personal circumstances, is not only a social justice imperative but also a way to reward talent, allocate resources effectively, and raise education and social outcomes in general.

This chapter examines, for the United States and a group of comparison countries, a set of indicators that map the dimensions of performance and equity assessed in PISA 2015. Since the focus of the PISA 2015 assessment was on science, this chapter examines the results for science in greater detail than those for reading and mathematics. Unless noted otherwise, references to figures and tables starting with "I" or "II" within parentheses refer to *PISA 2015 Results (Volume I): Excellence and Equity in Education* (OECD, 2016a) and *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools* (OECD, 2016b).

SCIENCE LEARNING OUTCOMES

Mean performance at the country level

In the 2015 PISA assessment, the United States ranked 19th in science, 20th in readings and 31st in mathematics out of 35 OECD countries (Tables I.2.14, I.4.2 and I.5.2).[1] In science and reading, there was no statistically significant difference between performance in the United States and the average performance across the OECD, while in mathematics, the United States performed below the OECD average.

As shown in Figure 2.1, the mean performance in the United States in science and reading has been stable since the last assessment in which they were the major domains: from 489 to 496 score points in science from 2006 to 2015, and from 500 to 497 points in reading from 2009 to 2015. However, mathematics performance in the United States fell significantly, from 481 to 470 points between 2012 (a year in which its performance was also below the OECD average) and 2015.

■ Figure 2.1 ■

United States' mean scores in science, reading and mathematics across PISA assessments

Mean score	Year of assessment					
	2015	2012	2009	2006	2003	2000
Science	496	497	502	489		
Mathematics	470	481	487	474	483	
Reading	497	498	500		495	504

Note: Grey cells indicate the major domain in each PISA assessment.
Source: OECD, PISA 2015 Database, Tables I.2.4a, I.4.4a and I.5.4a.

As shown in Figure 2.2, in 2015, the mean performance of the United States in science (496 score points) is statistically equivalent to that of countries with a performance ranging between 490 and 502 points; 12 other OECD countries perform at this level, including, for example, Austria, Belgium, Denmark, France, Poland and Sweden. However, the United States performs significantly below the four high-performing countries/economies discussed in this report: Canada (528), Estonia (534), Germany (509) and Hong Kong (China), a non-OECD member (523). Box 2.1 provides a context for comparing the performance of these countries and the United States.

■ Figure 2.2 ■

Mean science performance in the United States and selected PISA 2015 participants, at national and subnational levels

	Science scale					
	Mean score	95% confidence interval	Range of ranks			
			OECD countries		All countries/economies	
			Upper rank	Lower rank	Upper rank	Lower rank
Singapore	556	553 - 558			1	1
Alberta (Canada)	541	533 - 549				
British Columbia (Canada)	539	530 - 547				
Japan	538	533 - 544	1	2	2	3
Quebec (Canada)[1]	537	528 - 546				
Estonia	534	530 - 538	1	3	2	5
Finland	531	526 - 535	2	4	3	7
Massachusetts (United States)	529	516 - 542				
Canada	528	524 - 532	3	4	5	9
Ontario (Canada)	524	516 - 532				
Hong Kong (China)	523	518 - 528			7	10
Nova Scotia (Canada)	517	508 - 526				
Prince Edward Island (Canada)	515	504 - 525				
Germany	509	504 - 514	6	13	12	19
New Brunswick (Canada)	506	498 - 515				
Newfoundland and Labrador (Canada)	506	500 - 512				
North Carolina (United States)	502	493 - 512				
Manitoba (Canada)	499	490 - 509				
United States	496	490 - 502	15	25	21	31
Saskatchewan (Canada)	496	490 - 502				
Mexico	416	412 - 420	35	35	55	59
Puerto Rico[2]	403	391 - 415				
Brazil	401	396 - 405			62	64
Peru	397	392 - 401			63	64

1. Please note that results for the province of Quebec in this table should be treated with caution due to a possible non-response bias (see Annex A4 in OECD [2016a] for further details).
2. Puerto Rico is an unincorporated territory of the United States. As such, PISA results for the United States do not include Puerto Rico.
Note: OECD countries are shown in bold black. Partner countries and economies are shown in bold blue.
Regions are shown in black italics (OECD countries) or blue italics (partner countries)
Countries and economies are ranked in descending order of mean science performance.
Source: OECD, PISA 2015 Database, Table I.2.14.
StatLink http://dx.doi.org/10.1787/888933432060

Box 2.1 **A context for comparing the United States to other PISA participants**

This box compares the United States to the four high-performing countries/economies discussed in this report: Canada, Estonia, Germany and Hong Kong (China). These five countries differ in various ways and the high performance in the latter four countries in the PISA 2015 assessment cannot be attributed solely to a more favourable economic or demographic context. Examining policy measures applied in these countries and adapting them to the United States context, however, may help the United States improve its own performance and equity in education.

- *The United States is a wealthy country.* Its per capita GDP after accounting for purchasing power parity in 2014 was USD 54 629. This was just below the per capita GDP of Hong Kong (China), an international financial centre; roughly 20% higher than that of Canada and Germany; and almost twice as high as that of Estonia. Only three OECD countries (Luxembourg, Norway and Switzerland) have a higher GDP per capita than the United States.
- *The United States spends a large amount on education*. From the ages of 6 to 15, corresponding roughly to when children start primary education to when they sit the PISA assessment, the United States spends an average of USD 115 180 per student. This is over 20% more than the amount spent in Canada and Germany and almost twice as much as that spent in Estonia. Only five PISA-participating countries with data available (Luxembourg, Switzerland, Norway, Austria and Singapore) spend more per student than the United States.

...

- *There is more variation in socio-economic status in the United States than in the other four countries*. The PISA index of economic, social and cultural status (ESCS) is based on information about the occupational and education levels of students' parents and their home possessions. The average of this index across OECD countries was set to 0 with a standard deviation of 1. In the United States, the difference in the index between the 25th and 75th percentiles of its distribution was 2.54, compared to values ranging from 1.97 in Estonia to 2.43 in Germany. Indeed, only five countries (Spain, Luxembourg, Mexico, Portugal and Turkey) showed greater levels of socio-economic heterogeneity in PISA 2015.
- *The United States occupies an intermediate position in terms of the percentage of socio-economically disadvantaged students*. In the United States, 10.8% of students are found in the bottom two international deciles of the ESCS index. Fewer of Canada's, Estonia's and Germany's students are found in these two deciles but over one-quarter of students in Hong Kong (China) are in these two deciles.
- *A large but not extreme percentage of students in the United States have an immigrant background*. Over 30% of students in both Canada and Hong Kong (China) have an immigrant background, while this is the case for 23% of students in the United States. However, the United States still ranks high internationally, with only five other OECD countries (Luxembourg, Switzerland, Canada, New Zealand and Australia) having a greater share of immigrant students in its 15-year-old student population. On the other hand, only 10% of Estonian students have an immigrant background.
- *The United States is a large and complex country*. It is the world's third-most populous country and devolves certain powers in education to state-level and local-level departments and school boards. Germany and Canada are, like the United States, relatively large federal systems where individual states have their own governing systems for education. On the other hand, Hong Kong (China) is home to around 7 million people and Estonia is home to 1.3 million, and their education systems can be compared to a large district or a state education system, and a large school district or small state education system in the United States, respectively.

■ Table 2.1a ■

A comparison of the United States and four high-performing countries/economies in PISA 2015

	Per capita GDP (equivalent PPP[1] 2014)	Expenditure on education from ages 6 to 15 (equivalent PPP 2014)	Socio-economic heterogeneity: Difference between top and bottom quarters of ESCS[2] index distribution	Socio-economic heterogeneity: Difference between 5th and 95th percentiles of ESCS index distribution	Percentage of disadvantaged students (bottom two deciles of international ESCS index)	Percentage of immigrant students
	USD	USD	Index diff.	Index diff.	%	%
United States	54 629	11 5180	2.54	3.18	10.8	23.1
Canada	45 066	94 254	2.04	2.56	2.3	30.1
Estonia	28 140	63 858	1.97	2.38	4.8	10.0
Germany	46 401	92 214	2.43	2.92	7.2	16.9
Hong Kong (China)	55 195	m	2.42	2.97	26.3	35.1

1. PPP refers to purchasing power parity.
2. ESCS refers to the PISA index of economic, social and cultural status.
Source: OECD, PISA 2015 Database, Tables I.2.11, I.6.2a, I.6.4a and I.7.1.

Mean performance at the state level

There is, of course, significant performance variability within the United States, including between individual states. The United States did not measure the performance of all states individually, but students in public schools in two states (Massachusetts and North Carolina) were sampled separately, and reliable state-level results for public schools are available for these states. As shown in Figure 2.2, the mean score of Massachusetts (529) places it among top performers internationally, falling behind only the countries/economies of Singapore, Japan, Estonia, Chinese Taipei and Finland. Moreover, Massachusetts outperforms all subnational entities other than the Canadian provinces of Alberta, British Columbia and Quebec. The performance of North Carolina (mean score of 502) is comparable to that of the United States as a whole and of the Canadian provinces of New Brunswick, Newfoundland and Labrador, Manitoba and Saskatchewan.

The PISA assessment was also conducted in Puerto Rico, an unincorporated territory of the United States. Performance in Puerto Rico (mean science score of 403) was almost 100 points, or the equivalent of over two grade levels, below that in the 50 states. Indeed, it performed below the OECD country with the lowest mean performance, Mexico, but at a very similar level to some other Latin American countries, including Brazil and Peru.

Percentages of top-performing and low-performing students

To help users interpret what student scores mean in substantive terms, PISA scales are divided into proficiency levels. For PISA 2015, the range of difficulty of science tasks is represented by seven levels of science proficiency, including six levels aligned with those used in describing the outcomes of PISA 2006. These range from Level 6 (the highest) to Level 1a (formerly known as Level 1) and Level 1b, a new level at the bottom of the scale based on some of the easiest tasks included in the assessment (Figure I.2.6).

Attaining at least Level 2 is particularly important, as this level is considered to represent the baseline level of skills that all young adults should be expected to acquire by the time they leave compulsory education, to allow them to take advantage of further learning opportunities and to participate fully in the social, economic and civic life of modern societies in a globalised world (OECD, 2016c; OECD/Hanushek and Woessmann, 2015). Indeed, the Canadian Youth in Transition Survey, a longitudinal study of the 15-year-olds assessed by PISA in 2000 in Canada, showed that students who had attained Level 2 in reading were at least four times more likely to attend university than those who had not attained Level 2, after accounting for socio-economic characteristics (OECD, 2010).

Students who perform below proficiency Level 2 may be able to use basic or everyday scientific knowledge to recognise or identify aspects of familiar or simple scientific phenomena. However, they also often confuse key features of a scientific investigation, apply incorrect scientific information and mix personal beliefs with scientific facts in support of a decision. Students performing below Level 2 are classified as low performers, and the percentage of these low performers among the 15-year-olds assessed by PISA within a country/economy is a key indicator of the inclusiveness of its school system. The more inclusive countries/economies are those that succeed in helping a greater proportion of students to develop essential foundation skills.

At the other end of the performance distribution, students who perform at Levels 5 and 6 (the highest levels in the science assessment) can use abstract scientific ideas or concepts to explain unfamiliar and more complex phenomena, events and processes. Students at these two levels can evaluate ways of exploring a given question scientifically and identify limitations in interpretations of data sets. Students who attain Level 6 can, furthermore, draw on a range of interrelated scientific ideas and concepts from the physical, life, earth and space sciences, and use procedural and epistemic knowledge to offer explanatory hypotheses of novel scientific phenomena, events and processes that require taking multiple steps or making predictions. Students performing at these two levels are classified as top performers.

As shown in Figure 2.3, in 2015, some 20% of 15-year-old students in the United States did not reach the baseline Level 2 of science proficiency, compared to 21% on average across the OECD. However, the proportion of low performers was less than 10% in Estonia, Hong Kong (China), Japan, Macao (China), Singapore and Viet Nam.[2]

By contrast, 9% of 15-year-old students in the United States were top performers in science, similar to the 8% average across the OECD, but below the over 15% of 15-year-old students at this level observed in Japan, Singapore and Chinese Taipei. However, due to its size, 22% of the top-performing students in science in PISA 2015 reside in the United States. That is the highest proportion in any participating country/economy, ahead of Beijing, Shanghai, Jiangsu and Guangdong (China), Japan (both 13%) and Germany (6%) (Table I.2.18).

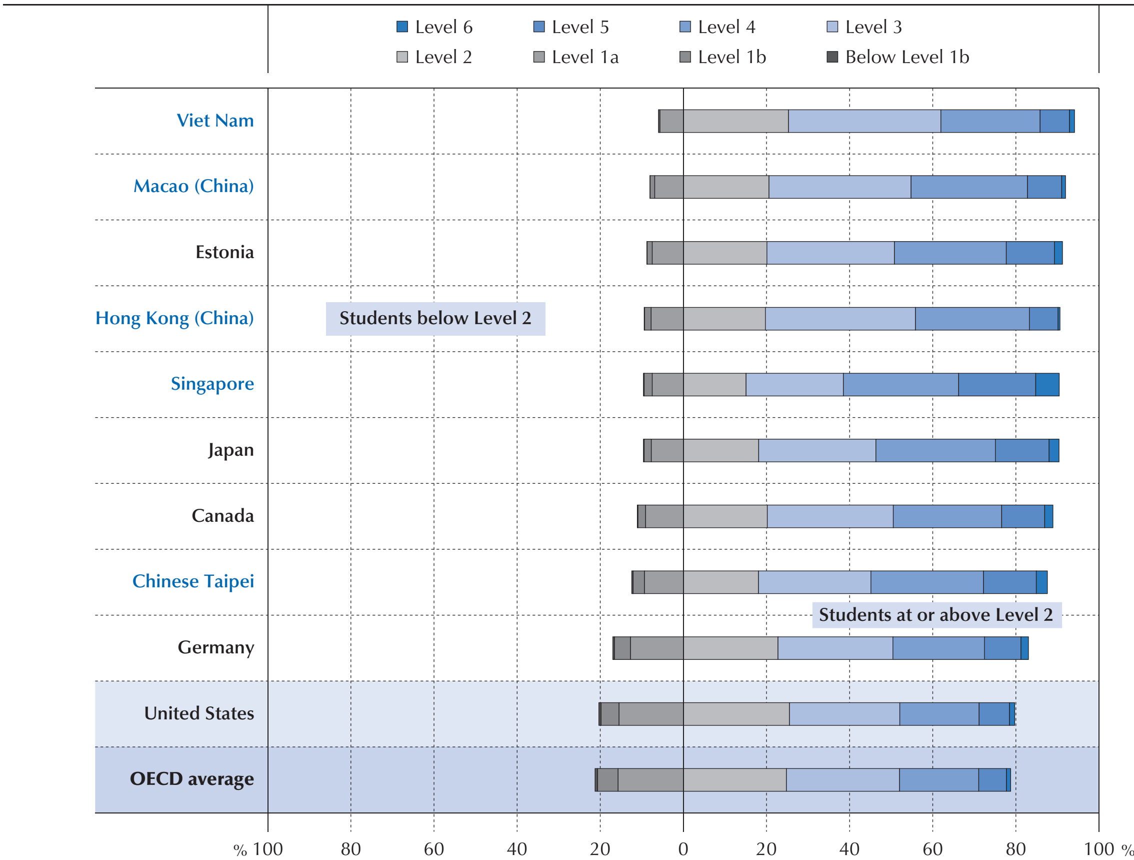
When other assessment domains are considered, about 19% of 15-year-old students in the United States did not attain Level 2 in reading proficiency, while 29% were unable to attain Level 2 in mathematics proficiency in 2015. This compares to the OECD-wide average of 20% in reading and 23% in mathematics. The proportion of top performers among students in the United States is 10% in reading and 6% in mathematics (Tables I.4.1a and I.5.1a). Across the OECD, 8% of students are top performers in reading and 11% are top performers in mathematics. In mathematics, the distribution of the performance of students in the United States is uniformly below the OECD average.

While the proportion of low performers in science in the United States was not different from the OECD average in 2015, the trend since 2006 shows some encouraging signs. The percentage of students performing below proficiency Level 2 in science decreased by 4 percentage points between PISA 2006 and 2015, a change that is not large enough to be statistically significant. However, when the trend is adjusted for changes in the demographic composition of students (i.e. students' age, gender and immigrant backgrounds) over this period, the decrease in the percentage of

low performers in science is larger (6 points) and significant (Tables I.2.2a-c). This positive trend is also reflected in the improved performance of students at the 10th percentile of the performance distribution in science, which increased by 18 score points between 2006 and 2015 (Table I.2.4b). By contrast, the percentage of top performers in science in the United States, whether measured by the percentage of students performing at Levels 5 and 6 or by the scores of students at the 90th percentile of the performance distribution, remained unchanged between 2006 and 2015.

■ Figure 2.3 ■

Students' proficiency in science in the United States and selected PISA 2015 participants



Note: OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries and economies are ranked in descending order of the percentage of students who perform at or above Level 2.
Source: OECD, PISA 2015 Database, Tables I.2.1a.
StatLink http://dx.doi.org/10.1787/888933432072

SCIENCE-RELATED ATTITUDES AND BELIEFS

The following section describes the attitudes and beliefs towards science held by students in the United States and across OECD countries. These indicators are based on information self-reported by students and are subject to both cultural differences and partial non-equivalence of items due to wording understood differently across languages. Hence, most of the comparisons made below relate to differences among subgroups of the student population within countries rather than between countries.

Epistemic beliefs

Science, as defined in PISA, encompasses not only knowledge of the natural world and of technological artefacts (content knowledge), but also knowledge of how such ideas are produced by scientists and an understanding of the goal of scientific enquiry and the nature of scientific claims (procedural and epistemic knowledge) (OECD, 2016c).

Epistemic beliefs, in particular, are individuals' representations about the nature, organisation and source of knowledge, such as what counts as true and how the validity of an argument can be established (Hofer and Pintrich, 1997). When students seek knowledge and understanding, adopt a questioning approach to all statements, search for data and their meaning, demand verification, respect logic and pay attention to premises, they can be said to have a scientific attitude

and to value scientific approaches to enquiry. Such beliefs and dispositions have been shown to be directly related to both students' ability to acquire new knowledge in science and their grades in school science (Mason et al., 2012).

PISA measured students' beliefs about the validity and limitations of scientific experiments and about the tentative and evolving nature of scientific knowledge through their opinions on six statements:

1. A good way to know if something is true is to do an experiment.
2. Ideas in science sometimes change.
3. Good answers are based on evidence from many different experiments.
4. It is good to try experiments more than once to make sure of [your] findings.
5. Sometimes scientists change their minds about what is true in science.
6. The ideas in science books sometimes change.

Students in the United States display high levels of epistemic beliefs. Over nine in ten students agreed with the second, third and fourth statements listed above, and over 86% of students agreed with each of the other three statements (Table I.2.12a). In the United States, 15-year-olds displayed higher levels of epistemic beliefs than their counterparts on average across OECD countries – with a 5 percentage point gap in favour of students in the United States in their levels of agreement with each question. Girls in the United States agree more often than boys to the second, third and fourth statements listed above (Table I.2.12c).

An increase in the index of epistemic beliefs by one unit was associated with a 32-point increase in the PISA science score among students in the United States, comparable to the 33-point increase observed across the OECD (Table 1.2.12b).[3]

Students' science-related career expectations

PISA 2015 asked students what occupation they expected to be working in when they were 30 years old. Students could enter any job title or description in an open-entry field. Their answers were classified according to the International Standard Classification of Occupations, 2008 edition (ISCO08). These coded answers were used to create an indicator of science-related career expectations, defined as careers that would require the study of science beyond compulsory education, typically in formal tertiary education. Within this large group of science-related occupations, four major groups were distinguished: science and engineering professionals; health professionals; science technicians and associate professionals; and information and communication technology (ICT) professionals.

As shown in Figure 2.4, 38% of 15-year-olds in the United States expect to work in a science-related career at age 30, ranking them second-highest among OECD countries (behind Mexico, at 41%), and over one-and-a-half times higher than the OECD average of 24%. Fewer than 20% of students in the top-performing countries/economies of Finland, Germany and Japan expect to have a science-related occupation. In contrast, in addition to Mexico, over 40% of students in Costa Rica, the Dominican Republic, Jordan and the United Arab Emirates (all of whom perform at least one grade level below the OECD average) expect to pursue a career in science. Overall, these high levels of expectations contrast with the relatively low share of students that, in most countries/economies, opt for science-related fields of study in higher education. While many students may value science-based careers, they are not always able to pursue them.

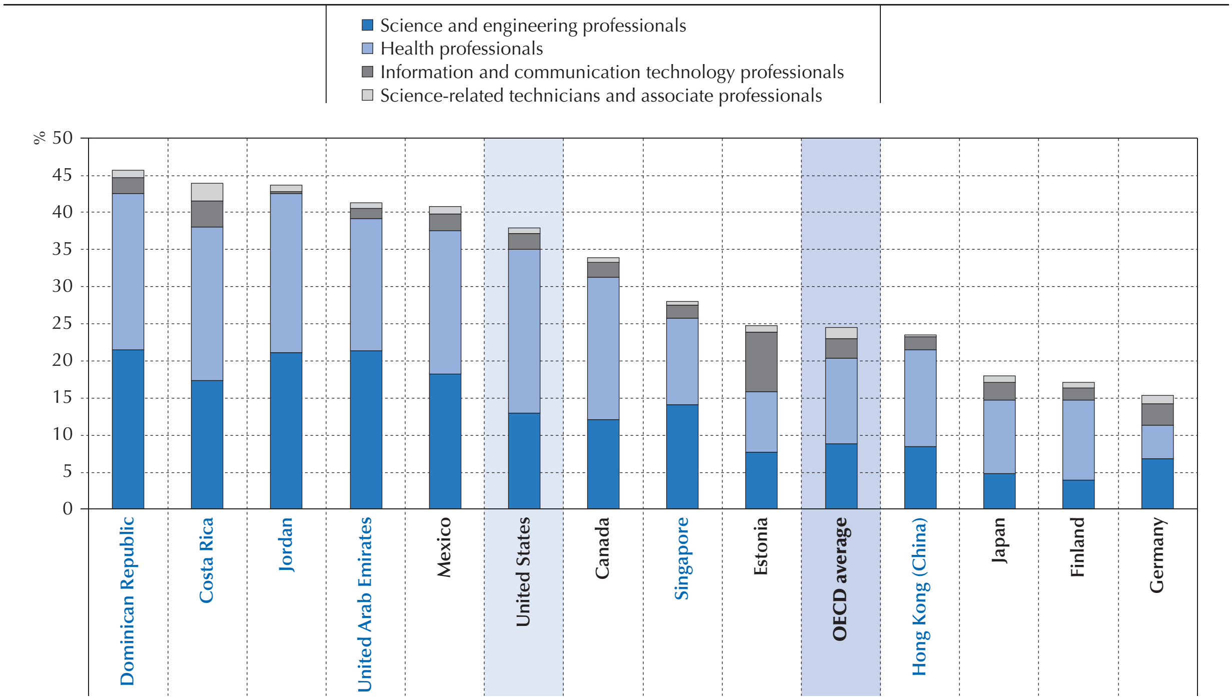
Disaggregating science-related careers into major groups of occupations shows that, in the United States, 13% of 15-year-olds expect to become science and engineering professionals; 22% expect to become health professionals; 2% expect to become ICT professionals; and 1% expect to become science-related technicians and associates (Figure 2.4). A similar proportion of students across the OECD expect to become ICT professionals and science-related technicians and associates. However, only 9% of 15-year-olds across OECD countries expect to become science and engineering professionals and only 12% expect to become health professionals.[4]

Students in the United States are also more likely than the OECD average to expect to work in science-related occupations at age 30, at all levels of performance on the PISA assessment (Table I.3.10b). In the United States, over half of all top performers in science (Levels 5 and 6) and over 28% of low performers (those who have not attained baseline Level 2) also expect to pursue a career in science. Interestingly, while on average across the OECD, top performers are over twice as likely as low performers to expect to work as health professionals at age 30 (16% of top performers vs. 7% of low performers), in the United States, top performers are less likely to expect to do so than low performers (19% of top performers vs. 20% of low performers) (Table I.3.11b).

■ Figure 2.4 ■

Students' science-related career expectations in the United States and selected PISA 2015 participants

Percentage of students who expect to work in science-related professional and technical occupations when they are 30



Note: OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries are ranked in descending order of the percentage of students who expect to work in science-related professional and technical occupations when they are 30.
Source: OECD, PISA 2015 Database, Table 1.3.10a.
StatLink http://dx.doi.org/10.1787/888933432284

On average across the OECD, a similar proportion of 15-year-old boys and girls expects to work in a science-related occupation at age 30 (25% of boys vs. 24% of girls) (Table I.3.10b). However, a different pattern is observed in the United States, where 43% of girls but only 33% of boys expect to work in a science-related occupation at age 30. This difference exists despite the fact that boys in the United States perform significantly better than girls on the PISA 2015 science assessment (Table I.2.8a).

Expectations of a career in health account for the difference between genders. In the United States, only 9% of boys expect this career path but 35% of girls do so, compared to 2% of boys and 7% of girls on average across the OECD. Boys were more likely than girls to expect to become science and engineering professionals (20% of boys vs. 6% of girls) and ICT professionals (4% of boys vs. 0.5% of girls), a gap that is also observed in many other OECD countries (Tables I.3.11a-c).

Science enjoyment

Intrinsic motivation refers to the drive to perform an activity purely for the joy gained from the activity itself. Students are intrinsically motivated to learn science when they want to do so not because of what they will be able to achieve by mastering new science concepts, but because they find learning science and working on science problems enjoyable (Ryan and Deci, 2009). Enjoyment of science affects the willingness of students to spend time and effort in science-related activities, their choice of electives, their self-image, and the type of careers they aspire to and choose to pursue (Nugent et al., 2015). Generally, students' enjoyment of science declines from elementary to high school (Archer et al., 2010). This may reflect the fact that, as students grow older, their interests become increasingly differentiated and specialised.

PISA 2015 measured science enjoyment by asking students to give their opinion on the following statements:

1. I generally have fun when learning science topics.
2. I like reading about science.

3. I am happy working on science topics.
4. I enjoy acquiring new knowledge in science.
5. I am interested in learning about science.

The United States compares favourably to the OECD average on each of these questions, exceeding it by between 4 to 14 percentage points (Table I.3.1a). For instance, while only 55% of students, on average across the OECD, said that they were happy working on science topics, 69% of students in the United States agreed with this statement. Likewise, 76% of students in the United States enjoyed acquiring new knowledge in science, compared to 66% across the OECD. Boys in the United States were 7 percentage points more likely to agree to each of these statements than girls (Table I.3.1c).

Within countries and across the OECD, the propensity to expect a science-related career is positively correlated with science performance and the enjoyment of science (Table I.3.13a). What is more, these two factors appear to reinforce each other: the increase in the likelihood of expecting a science career as a student's PISA science performance rises is larger for those students who enjoy science more, and lower for those with lower levels of enjoyment of science. While students in the United States are more likely, at any given level of performance and science enjoyment, to intend to pursue a science-related career than the OECD average, the effect of performance and science enjoyment is similar in the United States and across OECD countries.

Instrumental motivation

Instrumental motivation to learn science refers to the drive to learn science because students perceive it to be useful to them and to their future studies and careers (Wigfield and Eccles, 2000). PISA 2015 measured the extent to which students feel that science is relevant to their own study and career prospects through students' responses to the following statements:

1. Making an effort in science school subject(s) is worthwhile because it will help me in the work I want to do later on.
2. What I learn in school science subject(s) is worthwhile because I need it for what I want to do later on.
3. Studying science at school is worthwhile because what I learn will improve my career prospects.
4. Many things I learn in my school science subject(s) will help me get a job.

Students in the United States exhibited high levels of instrumental motivation, with 81% of them affirming that making an effort in their science school subject(s) is worthwhile because it will help them in the work they want to do later on, compared to 69% on average across OECD countries (Table I.3.3a). Over 70% of 15-year-olds in the United States agreed with the other three statements, compared to less than 70% on average across OECD countries (a percentage point gap of at least 7 points was observed for each question). Boys and girls in the United States respond to these questions at very similar levels (Table I.3.3c).

Furthermore, it is not only students who expect to work in a science-related field who agree that making an effort in their science school subject(s) is worthwhile because it will help them in their future career. About 89% of students in the United States who expect to be engineering professionals at the age of 30, and 93% of those who expect to be medical doctors, agree with this statement, but so do 79% of future social and religious professionals and 66% of future authors, journalists and linguists (Table I.3.11f). Similarly high numbers were observed in Canada, Hong Kong (China) and Singapore.

Self-efficacy

The term self-efficacy is used to describe students' belief that, through their actions, they can produce desired effects, such as solving a difficult problem or achieving a personal goal. This, in turn, is a powerful incentive to act or to persevere in the face of difficulties (Bandura, 1977).

Science self-efficacy refers to future-oriented judgments about one's competency in accomplishing particular goals in a specific context, where meeting these goals requires scientific abilities, such as explaining phenomena scientifically, evaluating and designing scientific enquiry, or interpreting data and evidence scientifically (Mason et al., 2012). Better performance in science leads to higher levels of self-efficacy, through positive feedback received from teachers, peers and parents, and the positive emotions associated with it. At the same time, students who have low self-efficacy are at high risk of underperforming in science, despite their abilities (Bandura, 1997). If students do not believe in their ability to accomplish particular tasks, they may not exert the effort needed to complete the task, and a lack of self-efficacy becomes a self-fulfilling prophecy. Self-efficacy in science has been related to students' performance and also to their career orientation and choice of courses (Nugent et al., 2015).

PISA 2015 asked students to report on how easy they thought it would be for them to:

1. Recognise the science question that underlies a newspaper report on a health issue.
2. Explain why earthquakes occur more frequently in some areas than in others.
3. Describe the role of antibiotics in the treatment of disease.
4. Identify the science question associated with the disposal of garbage.
5. Predict how changes to an environment will affect the survival of certain species.
6. Interpret the scientific information provided on the labelling of food items.
7. Discuss how new evidence can lead them to change their understanding about the possibility of life on Mars.
8. Identify the better of two explanations for the formation of acid rain.

For each of these, students could report that they "could do this easily", "could do this with a bit of effort", "would struggle do to this on [their] own" or "couldn't do this".

Students in the United States exhibited levels at or above OECD average for seven of the eight questions, even though their actual science knowledge and skills was just around the average level. In the United States, 34% of 15-year-olds said that they could easily predict how changes to an environment would affect the survival of certain species, compared to only 23% of students across OECD countries (Table I.3.4a). Similarly, 28% of students in the United States (compared to 21% on average across OECD countries) said that they could easily recognise the science question that underlies a newspaper report on a health issue. Self-efficacy among students in the United States is particularly higher on questions related to living systems, which is indeed the science-content subscale that the United States performs best on.

Boys in the United States are more likely than girls to report that they could easily perform each of the above tasks. However, the difference is not significant for tasks related to living systems but is significant for other tasks. This is consistent with the significantly higher performance of boys than girls in the physical systems and earth and space systems subscales of the PISA 2015 science assessment but the similar performance of boys and girls in the living systems subscale (Tables I.2.21d, I.2.22d and I.2.23d). This may also reflect the greater propensity of boys to expect to pursue careers as science and engineering professionals, compared to the greater propensity of girls to expect to pursue careers as health professionals.

In general, however, levels of self-efficacy among students in the United States may be somewhat unrealistic, given that they are not backed up by commensurate levels of performance. Students in Canada also exhibit relatively high levels of science self-efficacy and, differently from their peers in the United States, their high knowledge and skills are consistent with that self-perception. It is noteworthy that students in high-performing Hong Kong (China) exhibit low levels of self-efficacy, being 7 percentage points less likely compared to the OECD average to respond that they could easily do five of the eight tasks. Indeed, fewer than one in five students reported that they could easily do seven of the eight tasks presented to measure self-efficacy. This may reflect that students in East Asia are generally confronted with much higher expectations than students in the United States. It may also reflect cultural differences in what is perceived to be "easily" performed.

EQUITY IN THE DISTRIBUTION OF STUDENT OPPORTUNITIES AND OUTCOMES

How PISA examines equity in education

PISA analyses equity in education from three perspectives. First, it examines variation in the distribution of student outcomes, especially whether students acquire a baseline level of skills, as a way to assess the inclusiveness of school systems. Second, it looks at the impact of students' backgrounds on their outcomes at school, as a way to assess fairness. Third, it explores how access to educational resources and the incidence of sorting practices varies between students of different backgrounds, as a way to identify some of the factors that mediate their association with performance.

The first perspective was discussed in the previous section. The other two are discussed below, with a focus on differences in student outcomes related to students' socio-economic status. In PISA, a student's socio-economic background is estimated by the PISA index of economic, social and cultural status (ESCS), which is based on information about the student's home and background (Box 2.2).

Box 2.2 **Definition of socio-economic status in PISA**

Socio-economic status is a broad concept that summarises many different aspects of a student, school or school system. In PISA, a student's socio-economic status is estimated by the PISA index of economic, social and cultural status (ESCS), which is derived from variables related to students' family background: parents' education, parents' occupations, a number of home possessions that can be taken as proxies for material wealth and the number of books available in the home. The PISA index of economic, social and cultural status is a composite score derived from these indicators via Principal Component Analysis. It is constructed to be internationally comparable and standardised to have a mean of zero and a standard deviation of one for the population of students in OECD countries, with each country given equal weight.

In PISA 2015, the mean of the ESCS index in the United States is slightly above the OECD average. The index also shows a larger-than-average dispersion in the United States, as indicated both by its standard deviation and by the difference between the 5th and 95th percentiles of the index.

The ESCS index makes it possible to draw comparisons between students and schools with different socio-economic profiles. In this report, students are considered **socio-economically advantaged** if they are among the 25% of students with the highest values on the ESCS index in their country or economy. Students are classified as **socio-economically disadvantaged** if their values on the ESCS index are among the bottom 25% within their country or economy. By extension, schools are classified as socio-economically advantaged or disadvantaged within each country or economy, based on their students' mean values on the ESCS index.

Group differences in mean ESCS values reflect differences in the various dimensions of socio-economic status. For instance, in the United States, parents of socio-economically advantaged students are highly educated: virtually all have attained tertiary education (99%) and work in a skilled, white-collar occupation (98%). By contrast, 49% of parents of disadvantaged students have attained some post-secondary non-tertiary education as their highest level of formal schooling: 39% attained lower secondary education or less, and only 12% attained tertiary education. Few disadvantaged students have a parent working in a skilled occupation (9%), with many parents of these 15-year-olds working in semi-skilled, white-collar occupations (41%), and the majority (50%) working in elementary occupations or semi-skilled, blue-collar occupations. One of the home possessions that most clearly distinguishes students of different socio-economic profiles is the quantity of books at home. In the United States, 35% of advantaged students reported having more than 200 books at home, while this is the case for only 2% of their peers among disadvantaged students. Advantaged students also reported a greater availability of other resources, such as educational software (87%, compared to 48% among disadvantaged students (Table I.6.2b).

How socio-economic disparities relate to students' performance and attitudes towards science

PISA shows that, even in those countries and economies with high levels of performance, socio-economic status remains associated with significant differences in performance. Advantaged students tend to perform better than their disadvantaged peers by large margins. However, the link between socio-economic deprivation and low achievement is far from unbreakable, and many disadvantaged students succeed in attaining high levels of performance in PISA, not only within their own countries and economies, but also in international comparison.

Socio-economic status as a predictor of student performance

A key indicator of equity in education in PISA is the proportion of the variation in student performance within a country/economy that is explained by differences in students' socio-economic status. This measure, which PISA terms the strength of the socio-economic gradient, reflects how well socio-economic status predicts performance. When a student's actual performance is not the same as would be expected given his or her socio-economic status, the socio-economic gradient is considered to be weak. When socio-economic status becomes a good predictor of performance, the gradient is considered strong.

As shown in the second column of Figure 2.5, in the United States, 11.4% of the variation in student performance in the PISA 2015 science assessment was associated with socio-economic status. This percentage was slightly below but statistically comparable to the OECD average of 12.9%. In many of the high-performing countries/economies in PISA 2015, the relationship between student performance and socio-economic status was weaker than average. These

include Canada (8.8%), Estonia (7.8%) and Hong Kong (China) (4.6%), which shows one of the weakest socio-economic gradients among all PISA participants. By contrast, Germany (15.8%) is among the five high-performing systems with a stronger than average gradient, a group which also includes Singapore (16.7%).

■ Figure 2.5 ■

Socio-economic status and science performance in the United States and selected PISA 2015 participants

Results based on students' self-reports

	Performance in science	Percentage of variation in student performance in science explained by ESCS[1] (strength of the socio-economic gradient)	Score-point difference in science associated with one-unit increase in ESCS (slope of the socio-economic gradient)	Performance in science, by socio-economic status		Difference in science performance between students in the top quarter and students in the bottom quarter of ESCS
				Bottom quarter of ESCS	Top quarter of ESCS	
	Mean score	%	Score dif.	Mean score	Mean score	Score dif.
Singapore	556	16.8	47	497	609	113
Alberta (Canada)	541	7.4	31	513	576	63
British Columbia (Canada)	539	8.0	32	511	577	67
Quebec (Canada)	537	11.2	36	495	573	78
Estonia	534	7.8	32	504	573	69
Massachusetts (United States)	529	14.1	37	481	578	97
Canada	528	8.8	34	492	563	71
Ontario (Canada)	524	8.3	34	487	558	70
Hong Kong (China)	523	4.9	19	504	550	45
Nova Scotia (Canada)	517	6.5	27	491	548	57
Prince Edward Island (Canada)	515	2.8	18	493	527	34
United Kingdom	509	10.5	37	473	557	84
Germany	509	15.8	42	466	569	103
New Brunswick (Canada)	506	7.3	29	475	544	70
Newfoundland and Labrador (Canada)	506	7.0	27	473	532	58
Switzerland	506	15.6	43	455	561	106
North Carolina (United States)	502	9.2	29	470	548	78
Manitoba (Canada)	499	8.0	29	468	533	65
United States	496	11.4	33	457	546	90
Saskatchewan (Canada)	496	5.8	25	470	524	54
OECD average	**493**	**12.9**	**38**	**452**	**540**	**88**
Mexico	416	10.9	19	386	446	60
Puerto Rico[2]	403	17.8	41	366	458	92

1. ESCS refers to the PISA index of economic, social and cultural status.
2. Puerto Rico is an unincorporated territory of the United States. As such, PISA results for the United States do not include Puerto Rico.
Note: OECD countries are shown in bold black. Partner countries and economies are shown in bold blue.
Regions are shown in black italics (OECD countries) or blue italics (partner countries).
Countries and economies are ranked in descending order of mean science performance.
Source: OECD, PISA 2015 Database, Table I.6.3a.

Differences in performance associated with socio-economic status

Another important indicator of equity is the average impact of socio-economic status on performance, which PISA refers to as the slope of the socio-economic gradient. The slope reflects the average difference in performance between two students whose socio-economic status differs by one unit on the ESCS index. As such, it is a summary measure of the differences in performance observed across socio-economic groups.

As shown in the third column of Figure 2.5, a one-unit increase on the ESCS index was associated with an increase of 38 score points in the PISA 2015 science assessment, on average across OECD countries. In the United States, the associated increase was 33 score points, indicating a flatter socio-economic gradient than average. This is similar to the average impact of socio-economic status on performance in Canada (34) and Estonia (32), significantly above the average impact in Hong Kong (China) (19), and significantly below the average impact in Germany (42), which has a steeper slope than average.

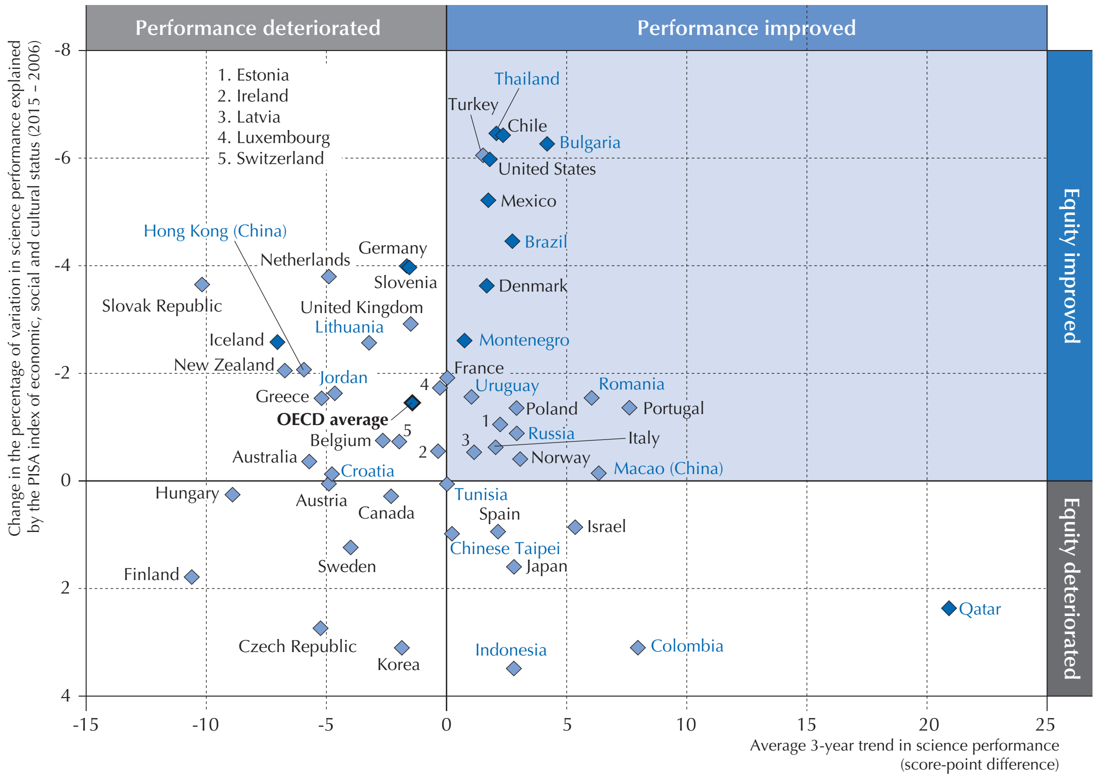
A complementary measure of the impact of socio-economic status on performance is the difference in performance between students at both ends of the socio-economic ladder. As shown in the last column of Figure 2.5, on average across OECD countries, advantaged students (those in the top quarter of the distribution on the ESCS index within their country/economy) score 88 points higher in science in PISA 2015 than disadvantaged students (those in the bottom quarter of the distribution). In the United States, the performance difference between these two groups of students was similar, 90 score points in science. By this measure, the United States has a lower level of equity than Canada (71 score points), Estonia (69 score points) and Hong Kong (China) (where the difference is 45 score points) and a higher level of equity than Germany, where the difference is 103 score points.

Change in the association between socio-economic status and student performance between 2006 and 2015

By analysing data across different PISA assessments, it is possible to identify those school systems that have become more or less equitable over time and to determine whether trends in equity are mirrored by trends in performance. In order to allow for trend analyses, in PISA 2015, the ESCS index was recomputed for earlier assessments using the same methodology as in 2015 (see *PISA 2015 Technical Report* [OECD, forthcoming]). In this report, trends in equity are analysed by comparing the evolution of the strength and the slopes of the socio-economic gradient between 2006 and 2015, two rounds of PISA when science was the major domain of assessment. Figures 2.6 and 2.7 show these changes in the context of countries/economies' trends in performance between 2006 and 2015.

■ Figure 2.6 ■

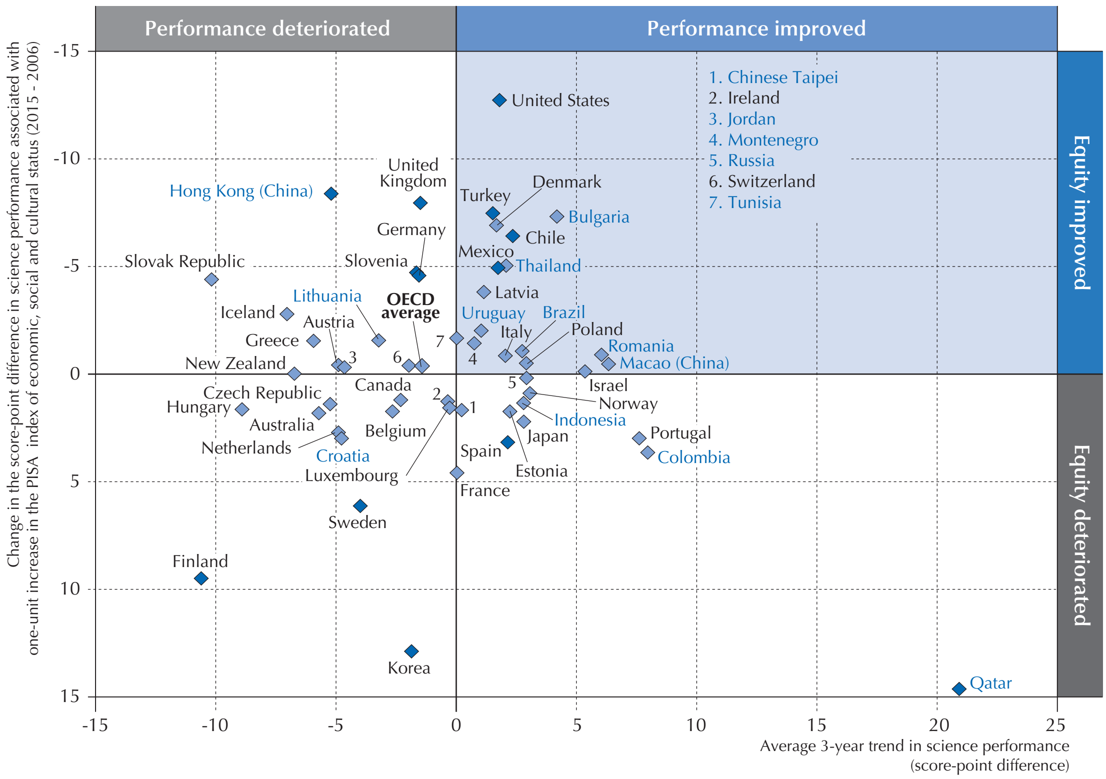
Change between 2006 and 2015 in the strength of the socio-economic gradient and average three-year trend in science performance



Notes: Only countries and economies with available data are shown.
Changes in equity between 2006 and 2015 that are statistically significant are indicated in a darker tone (see Annex A3 in OECD [2016a]).
The average three-year trend is the average rate of change, per three-year period, between the earliest available measurement in PISA and PISA 2015. For countries and economies with more than one available measurement, the average three-year trend is calculated with a linear regression model. This model takes into account that Costa Rica, Georgia, Malta and Moldova conducted the PISA 2009 assessment in 2010 as part of PISA 2009+.
Source: OECD, PISA 2015 Database, Table I.6.17.
StatLink http://dx.doi.org/10.1787/888933432843

■ Figure 2.7 ■

Change between 2006 and 2015 in the slope of the socio-economic gradient and average three-year trend in science performance



Notes: Only countries and economies with available data are shown.
Changes in equity between 2006 and 2015 that are statistically significant are indicated in a darker tone (see Annex A3 in OECD [2016]).
The average three-year trend is the average rate of change, per three-year period, between the earliest available measurement in PISA and PISA 2015. For countries and economies with more than one available measurement, the average three-year trend is calculated with a linear regression model. This model takes into account that Costa Rica, Georgia, Malta and Moldova conducted the PISA 2009 assessment in 2010 as part of PISA 2009+.
Source: OECD, PISA 2015 Database, Table I.6.17.
StatLink http://dx.doi.org/10.1787/888933432855

In 2006, 17% of the variation in students' science performance in the United States could be explained by students' socio-economic status, a stronger socio-economic gradient than the OECD average (14%). And a one-unit change in the ESCS index – which corresponds to the difference between students with average socio-economic status and disadvantaged students – was associated with a difference in science performance of 46 score points, which means that the socio-economic gradient was also steeper than the OECD average (39 points). By 2015, however, the degree to which socio-economic status predicted student performance in science in the United States decreased by 6 percentage points, while the difference in performance between students separated by standard deviation on the ESCS index decreased by 13 score points. By comparison, on average across OECD countries, the strength of the gradient decreased by 1 percentage point, while the slope remained unchanged.

Considering both indicators together, the weakening of the association between socio-economic status and student performance in the United States since 2006 represents the largest improvement in equity among all the countries and economies that participated in PISA 2006 and PISA 2015. Other OECD countries achieving significant reductions in both the strength and the slope of the socio-economic gradient were Chile, Denmark, Mexico and Slovenia (Table I.6.16). Among the comparison countries, in Germany the percentage of variation in performance explained by socio-economic status decreased by 4 percentage points, and in Hong Kong (China) the impact of a one-unit change in the ESCS index was reduced by 8 score points. No significant changes in these indicators are observed in Canada or Estonia.

The positive trend in equity in education in the United States since 2006 should also be considered in light of its stable level of achievement over this period. While equity improved, overall performance remained essentially unchanged – a result that is also observed among many of the countries and economies where the influence of socio-economic status on student performance decreased between PISA 2006 and PISA 2015. The fact that the United States' average performance in science did not change while differences in performance associated with students' socio-economic status became smaller means that trends in performance were not uniform across students of different socio-economic profiles. Indeed, PISA 2015 results suggest that the increase in equity in the United States was largely driven by performance gains among disadvantaged students, rather by performance losses among their advantaged peers. Trends in the percentage of low-performing students (Table I.2.4b) and in the percentage of disadvantaged students performing above expectations (see the discussion about resilient students below) support this claim. However, improvements in performance among students from disadvantaged socio-economic backgrounds were not large enough to translate into a significant change in the country's mean performance in science.

Performance below proficiency Level 2, by socio-economic background

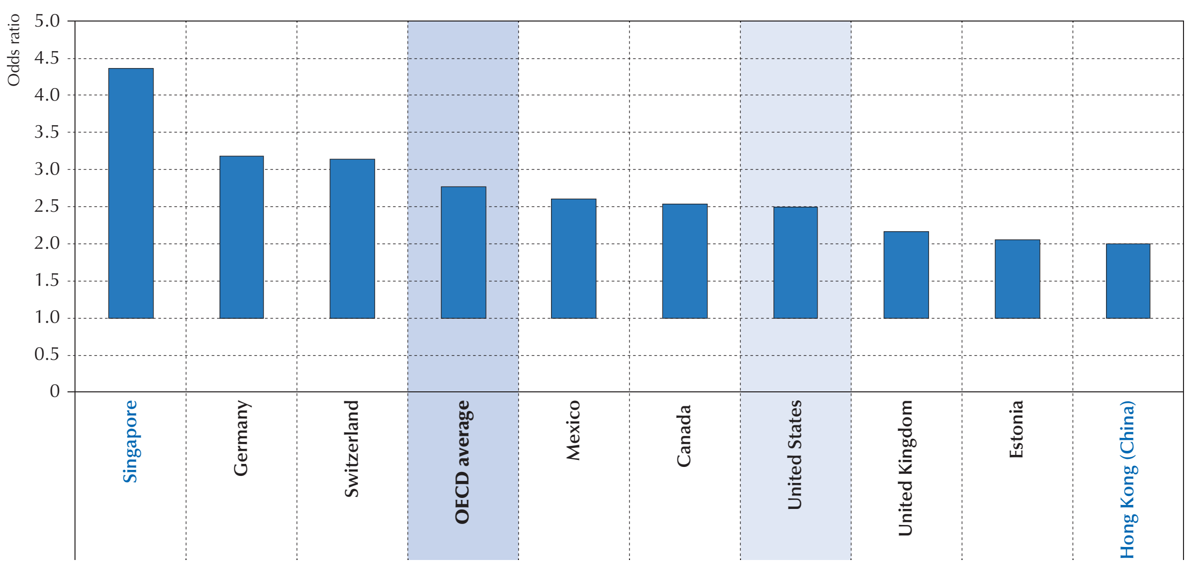
Equitable school systems are characterised by being inclusive, ensuring that the majority of students, regardless of their backgrounds, attain a baseline level of skills. In PISA 2015, a higher likelihood of low performance was observed among disadvantaged students (relative to their peers with average or high socio-economic status) in all PISA-participating countries/economies (Table I.6.6a). This result speaks to the pervasiveness of the impact of socio-economic circumstances on student achievement, no matter the level at which school systems perform as a whole.

As shown in Figure 2.8, in the United States, disadvantaged students were 2.5 times more likely than their more advantaged peers to be low performers, slightly below the average likelihood observed across OECD countries. Estonia and Hong Kong (China) show greater levels of equity in this respect. In Germany, the likelihood of low performance among disadvantaged students is higher than in the United States.

■ Figure 2.8 ■

Likelihood of low performance among disadvantaged students in the United States

Compared to selected PISA 2015 participants



Notes: All coefficients are statistically significant (see Annex A3 in OECD [2016a]).
A socio-economically disadvantaged student is a student in the bottom quarter of the distribution of the PISA index of economic, social and cultural status (ESCS) within his or her country/economy.
OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries and economies are ranked in descending order of the likelihood that students in the bottom quarter of ESCS score below Level 2 in science, relative to non-disadvantaged students.
Source: OECD, PISA 2015 Database, Table 1.6.6a.
StatLink http://dx.doi.org/10.1787/888933432777

Resilient students

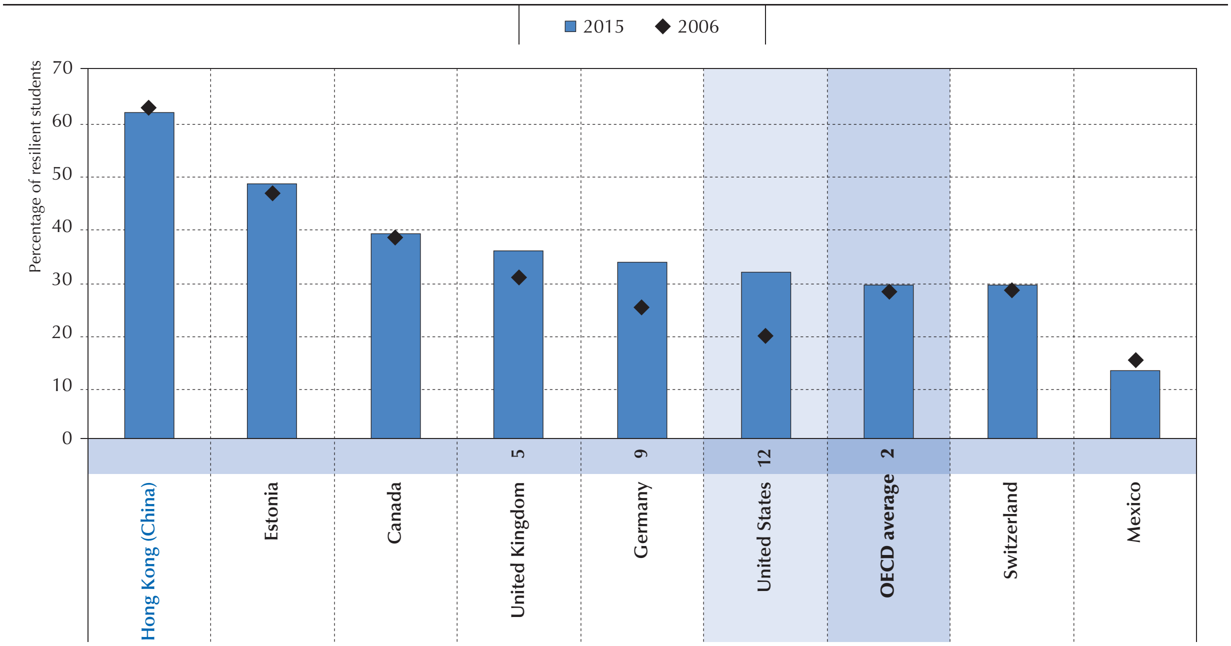
Evidence that higher levels of equity and performance need not be at odds comes from the finding that many disadvantaged students, schools and school systems achieve better performance in PISA than predicted by their socio-economic status. As such, they are considered to be resilient.[5]

Figure 2.9 presents the percentage of resilient students in the United States and comparison countries in the PISA 2015 and PISA 2006 assessments. In PISA 2015, 32% of disadvantaged students in the United States beat the odds against

them and score among the top quarter of students in all participating countries, after accounting for socio-economic status – a proportion that is comparable to the OECD average (29%). The percentage of resilient students is above the OECD average in most of the high-performing countries/economies included in the comparison, but it is particularly high in Hong Kong (China), where 62% of disadvantaged students achieve better performance than expected on the basis of their socio-economic background. While the proportion of resilient students is positively correlated with the mean performance of countries/economies in PISA, student resiliency in Hong Kong (China) (62%%) is higher than in Canada (39%) and Estonia (48%), two countries with mean scores similar to or higher than Hong Kong (China) in the science assessment.

■ Figure 2.9 ■

Percentage of resilient students in PISA 2015 and PISA 2006 in the United States and selected PISA 2015 participants



1. A student is classified as resilient if he or she is in the bottom quarter of the PISA index of economic, social and cultural status (ESCS) in the country/economy of assessment and performs in the top quarter of students among all countries/economies, after accounting for socio-economic status.

Notes: The percentage-point difference between 2006 and 2015 in the share of resilient students is shown next to the country/economy name. Only statistically signicant differences are shown (see Annex A3 in OECD [2016a]).

OECD countries are shown in black. Partner countries and economies are shown in blue.

Countries and economies are ranked in descending order of the percentage of resilient students in 2015.

Source: OECD, PISA 2015 Database, Table 1.6.7.

StatLink http://dx.doi.org/10.1787/888933432786

Figure 2.9 also shows that, on average across OECD countries, the percentage of resilient students grew by 2 percentage points between 2006 and 2015. However, a much more positive trend is observed in the United States, where the proportion of disadvantaged students performing above expectations increased by 12 percentage points over the period, while it increased by 9 percentage points in Germany and 5 percentage points in the United Kingdom. A common pattern among these three countries is that they achieved greater success in 2015 than in 2006 in breaking the link between socio-economic disadvantage and low performance in a context of stable mean performance (Table I.6.16).

Science performance by international deciles of the PISA index of economic, social and cultural status

PISA can be used to compare not only the outcomes of students with a similar relative socio-economic position within their countries, but also the performance of students sharing similar circumstances across countries. Such comparisons can be carried out by placing students on international deciles of the PISA index of social, economic and cultural status, that is, on a scale that measures students' socio-economic standing across rather than within national borders.

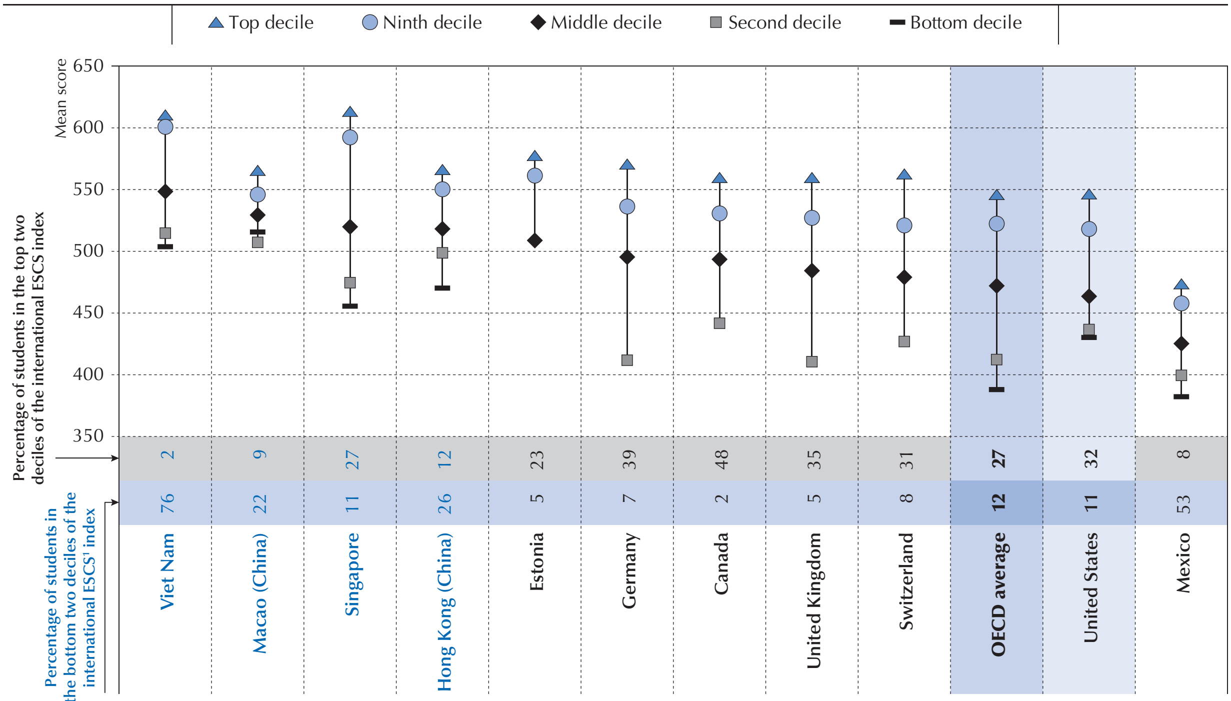
As shown in Figure 2.10, students in the United States at the bottom, middle and top of the international distribution of the ESCS index perform in science at levels similar to those of students with similar socio-economic profiles across OECD countries. However, the performance of students of similar socio-economic status can vary widely across school systems. For instance, in Hong Kong (China), Macao (China) and Viet Nam, students facing the greatest disadvantage (those in the bottom two international deciles of the distribution of the ESCS index) score between 50 and 80 points higher than their peers in the United States. And in Canada and Estonia, students in the middle 10% of the distribution score between 25 and 50 points higher in science than similar students in the United States. And while the proportion of 15-year-old students in the bottom deciles of the international scale is smaller in Canada (2%) and Estonia (5%) than in the United States (11%), it is at least double in Hong Kong (China) (26%) and Macao (China) (22%).

Among the comparison countries, Germany, Singapore and Switzerland show the largest dispersion in performance between students in the top and bottom international deciles of the socio-economic scale.

■ Figure 2.10 ■

Mean performance in science, by international decile of socio-economic status, in the United States

Compared to selected PISA 2015 participants



1. ESCS refers to the PISA index of economic, social and cultural status.

Notes: International deciles refer to the distribution of the PISA index of economic, social and cultural status across all countries and economies.

Performance estimates are only shown for deciles where there was a sufficient number of observations.

OECD countries are shown in black. Partner countries and economies are shown in blue.

Countries and economies are ranked in descending order of the mean science performance of students in the bottom decile of the PISA index of economic, social and cultural status.

Source: OECD, PISA 2015 Database, Table 1.6.4a.

StatLink http://dx.doi.org/10.1787/888933432757

Differences in students' science-related career expectations related to socio-economic status

Countries and economies across the world are trying to promote students' interest in science and technology careers by focusing on the affective dimensions of learning science. Equity in access to these occupations is a related concern, as disadvantaged students are often under-represented in scientific fields of study. This is partly due to their lower average performance relative to students from more privileged backgrounds, but also to differences in their attitudes towards learning science.

In PISA 2015, disadvantaged students in the United States were 20% less likely than advantaged students with similar performance in science to expect to work in a science-related occupation by age 30 (Table I.6.8). In this respect, the United States is no exception to the average result across OECD countries. However, in the four comparison countries/economies, and despite their higher levels of equity on most of the dimensions linking socio-economic status to science learning outcomes, the relative likelihood that disadvantaged students expect to pursue a career in science, after accounting for their performance, is lower than in the United States. For instance, in Germany, students from low socio-economic backgrounds are only half as likely as their peers from advantaged backgrounds to see themselves as working in an occupation that requires further science training (Table I.6.8).

How performance relates to socio-economic disparities between and within schools

Ensuring consistently high standards across schools is a formidable challenge for any school system. Common concerns behind disparities in the socio-economic composition of schools are inequalities in the distribution of resources available at the school level, and student peer effects, both of which may lead to greater disparities in student outcomes. Research in the United States documents a close link between segregation along economic and racial/ethnic lines (Orfield and Lee, 2005) and suggests that income segregation between school districts has grown over the last 20 years (Reardon and Owens, 2014).

The structure of school systems can also be associated with variation in student outcomes. Systems with small between-school variations in performance tend to be those that are comprehensive, meaning that they do not sort students by programme or school based on ability. By contrast, systems setting different tracks or pathways through school levels and inviting students to choose among them at an earlier age tend to show larger between-school variations and a greater impact of social background on learning outcomes.

Variation in performance between and within schools

In PISA 2015, 30% of performance differences in science were observed between schools and 70% were observed within schools, on average across OECD countries. The extent of between-school differences in performance varies widely across school systems, partly as a function of the overall level of variation.

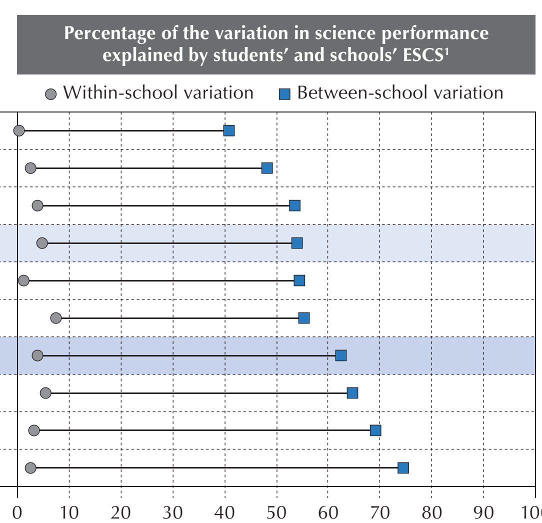
As shown in the left panel of Figure 2.11, the level of between-school variation in performance in the United States (21%) is below the OECD average, while within-school variation (87%) is higher than average. This is noteworthy, given that school systems where the overall level of variation is higher than the OECD average – as is the case in the United States, by 8 percentage points – tend to also display greater variation in performance between schools, as done, for instance, by Germany, Singapore and Switzerland.

■ Figure 2.11 ■

Performance differences between and within schools and socio-economic status in the United States

Compared to selected PISA 2015 participants

Total variation as a percentage of the average total variation in science performance across OECD countries	Within-school variation as a percentage of the average total variation in science performance across OECD countries	Between-school variation as a percentage of the average total variation in science performance across OECD countries	
%	%	%	
72	50	22	Hong Kong (China)
87	71	17	Estonia
94	80	14	Canada
108	87	21	United States
57	40	17	Mexico
111	69	42	Switzerland
100	**69**	**30**	**OECD average**
120	78	42	Singapore
110	86	24	United Kingdom
109	61	48	Germany



1. ESCS refers to the PISA index of economic, social and cultural status.
Notes: OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries are ranked in the ascending order of the percentage of between-school variation in science performance explained by the PISA index of economic, social and cultural status.
Source: OECD, PISA 2015 Database, Tables I.6.9 and I.6.12a.
StatLink http://dx.doi.org/10.1787/888933432819

Below-average differences across students in different schools coexist with an overall level of variation below the OECD average in Canada, Estonia and Hong Kong (China). In this comparison, Canada stands out as the country/economy with the lowest percentage of between-school variation (14%), while having an overall level of variation that is only 6 percentage points below the OECD average. Because Canada, Estonia and Hong Kong (China) also manage to achieve higher-than-average mean performance in science, families in these countries/economies can expect that, no matter which school their children attend, they are likely to achieve at high levels.

Alongside the degree of variation in performance and its distribution across students attending the same or different schools, an important question from the equity perspective is how much of this variation, and in particular that observed between schools, is related to the socio-economic status of students and schools. This is an indicator of the success of school systems in weakening the relationship between disparities in performance and the socio-economic composition of schools. This association is shown in the right panel of Figure 2.11.

In both the United States and Canada, 54% of the performance differences observed across students in different schools can be accounted for by the socio-economic status of students and schools, as compared to 63% on average across OECD countries. In Estonia and Hong Kong (China), socio-economic status accounts for less than half of the variation in performance across schools, whereas in Germany, Singapore and the United Kingdom, it accounts for at least two-thirds of this variation.

Performance differences associated with schools' socio-economic profiles

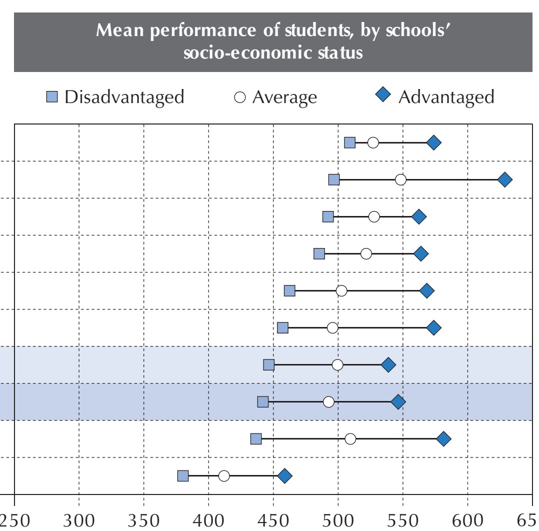
As shown in Figure 2.12, in the United States, students attending advantaged schools have a mean performance of 530 score points in the PISA 2015 science assessment, while students in disadvantaged schools have a mean performance of 447 points. This implies that a difference of 91 score points separates the performance of students attending schools in the top and bottom quarters of the ESCS index in the country, a gap that is lower than the average observed across OECD countries (104 points), but larger than the difference found in Estonia (64 points), Canada (69 points) and Hong Kong (China) (78 points). These gaps in performance should be seen in light of the dispersion of the mean values of the ESCS index of students in advantaged and disadvantaged schools, which are larger in the United States than in the other three countries.

■ Figure 2.12 ■

Student performance in science, by schools' socio-economic profile in the United States

Compared to selected PISA 2015 participants

Average socio-economic status of students attending a…			
Disadvantaged school[1]	Average school[2]	Advantaged school[3]	
-0.44	0.04	0.56	Estonia
-0.51	-0.04	0.72	Singapore
0.05	0.54	0.99	Canada
-1.05	-0.63	0.16	Hong Kong (China)
-0.31	0.18	0.77	United Kingdom
-0.36	0.09	0.75	Switzerland
-0.61	0.12	0.77	United States
-0.62	**-0.05**	**0.57**	**OECD average**
-0.52	0.08	0.75	Germany
-2.22	-1.24	-0.18	Mexico



1. A socio-economically disadvantaged school is a school in the bottom quarter of the distribution of the school-level PISA index of economic, social and cultural status (ESCS) within each country/economy.
2. A socio-economically average school is a school in the second and third quarters of the distribution of the school-level PISA index of economic, social and cultural status (ESCS) within each country/economy.
3. A socio-economically advantaged school is a school in the top quarter of the distribution of the school-level PISA index of economic, social and cultural status (ESCS) within each country/economy.
Notes: OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries and economies are ranked in descending order of the mean performance in science of students attending disadvantaged schools.
Source: OECD, PISA 2015 Database, Table I.6.11.
StatLink http://dx.doi.org/10.1787/888933432803

Policy options based on the relationship between performance and socio-economic status

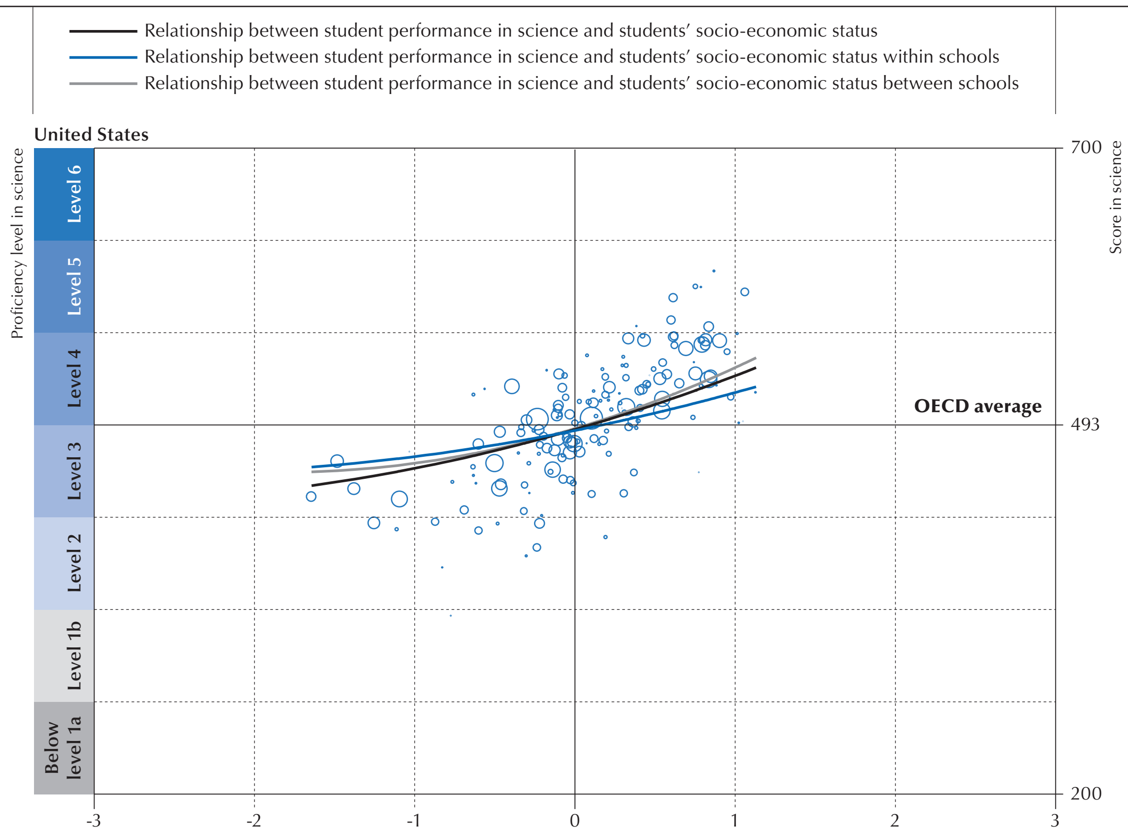
PISA provides a framework for policies to improve achievement and equity in education based on the pattern of association between performance and socio-economic status (Willms, 2006; OECD, 2013). This association is reflected in different aspects of the socio-economic gradient in performance observed in a country or economy. The strength of the gradient provides an indication of the extent to which education policies should target socio-economically disadvantaged students specifically, or low-performing students in general. If the relationship between social background and performance is weak, then other factors are likely to have greater bearing on student achievement, and focusing on students with low socio-economic status might not be so effective. By contrast, when the relationship is strong, then effective policies would be those that eliminate barriers to high performance linked to socio-economic disadvantage. In turn, the slope of the gradient shows the magnitude of the impact on performance that socio-economically targeted policies could potentially have.

As shown in Figure 2.13, in the United States the relationship between socio-economic background and student performance in science (displayed here at the school level) is far from deterministic. The figure shows that, at any level of the ESCS index, average school performance in the PISA 2015 science assessment can vary significantly. However, while the blue line depicts a relatively weak relationship between student performance and socio-economic status within schools, the grey line indicates that this association is stronger between schools, mainly driven by the higher performance of students attending advantaged schools.

The United States is a country where socio-economic status has an average predictive power on student performance (average strength), but where the impact of socio-economic status on performance is less pronounced than in other OECD countries (flat slope). In countries with this profile, a combination of universal policies to improve performance across the board – such as increasing the amount or quality of the time students spend at school – and policies providing more and better resources to disadvantaged schools may yield the best results.

■ Figure 2.13 ■

Relationship between school performance and schools' socio-economic profile in the United States



Note: The size of the bubbles represents the schools' size.
Source: OECD, PISA 2015 Database.

FACTORS ASSOCIATED WITH EQUITY AND INEQUITY

Shortage of educational material and staff, by schools' socio-economic profiles

A potential source of inequity in learning opportunities and outcomes lies in the distribution of resources across students and schools. A positive relationship between the socio-economic profile of schools and the quantity or quality of resources they can mobilise to support student learning means that schools may be contributing to – rather than reducing – any disparities in performance rooted in students' family environments. A negative relationship means that schools may be in a better position to reduce such disparities.

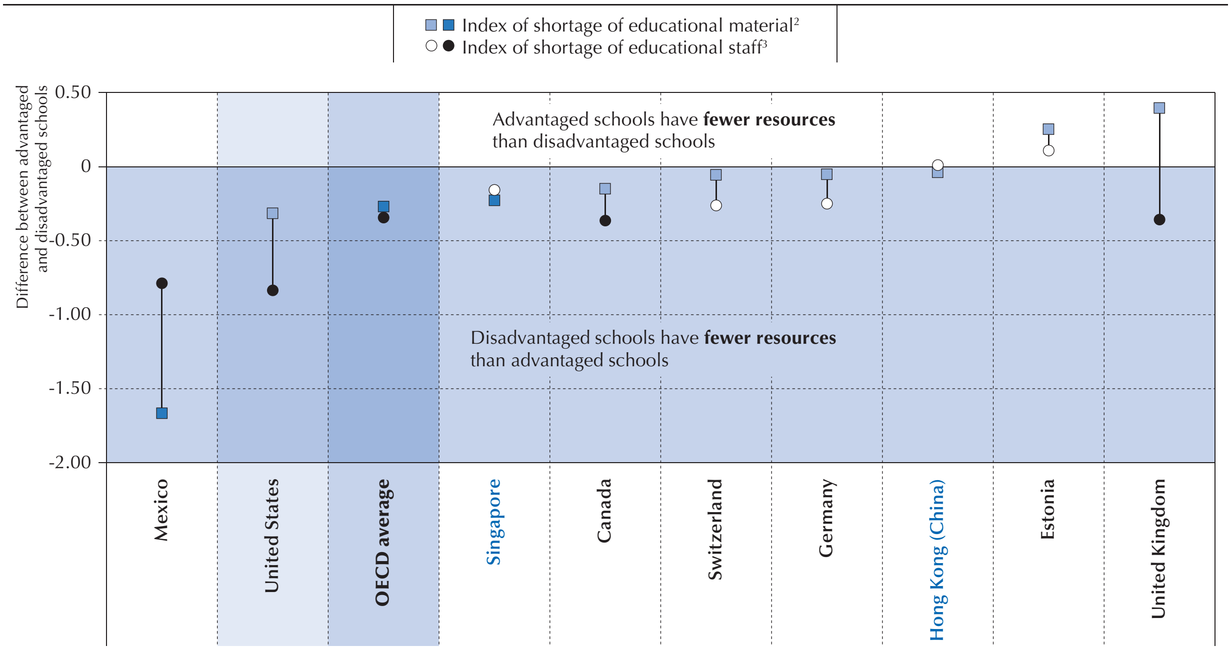
PISA 2015 provides two summary measures of the availability of educational resources at the school level: the index of shortage of educational material and the index of shortage of educational staff. Both indices combine school principals' responses to questions about whether their school's capacity to provide instruction is hindered by a shortage or inadequacy of either material resources (e.g. textbooks, IT equipment, laboratory material or physical infrastructure) or human resources (including both teaching and assisting staff).

As shown in Figure 2.14, in the United States, principals in schools serving disadvantaged students are more likely than principals of schools with a more privileged socio-economic intake to report a shortage of human resources – that is, that the number or qualifications of their teaching or assisting staff is short of meeting needs in their schools. In this respect, differences in resources by schools' socio-economic composition are greater in the United States than on average across OECD countries, and comparable to the differences observed in Mexico. Principals of advantaged and disadvantaged schools in Canada and the United Kingdom also report significant, albeit less pronounced, differences in the availability of human resources.

By contrast, PISA 2015 suggests that, in the United States, no significant differences exist between advantaged and disadvantaged students in terms of access to material resources (e.g. equipment and infrastructure) in their schools, a result in line with most of the comparison countries.

■ Figure 2.14 ■

Differences in educational resources between advantaged and disadvantaged[1] schools in the United States and selected PISA 2015 participants



1. A socio-economically advantaged school is a school in the top quarter of the distribution of the school-level PISA index of economic, social and cultural status (ESCS) within each country/economy. A socio-economically disadvantaged school is a school in the bottom quarter of the same distribution within each country/economy.
2. The index of shortage of educational material is measured by an index summarising school principals' agreement with four statements about whether the school's capacity to provide instruction is hindered by a lack of and/or inadequate educational materials, including physical infrastructure.
3. The index of shortage of educational staff is measured by an index summarising school principals' agreement with four statements about whether the school's capacity to provide instruction is hindered by a lack and/or inadequate qualifications of the school staff.

Note: Statistically significant differences between advantaged and disadvantaged schools are marked in a darker tone (see Annex A3 in OECD [2016a]).
OECD countries are shown in black. Partner countries and economies are shown in blue.
Countries and economies are ranked in ascending order of the difference in index of shortage of educational material between advantaged and disadvantaged schools.
Source: OECD, PISA 2015 Database, Table I.6.13.
StatLink http://dx.doi.org/10.1787/888933432823

Opportunity to learn: Instruction time in science

Differences in student performance in science related to socio-economic status can also be rooted in disparities in the amount of time devoted to learning science in school, as instruction time is a major component of opportunity to learn (Schmidt et al., 2015; OECD, 2016d).

PISA 2015 asked students how many regular science lessons they are required to attend per week and how much time they spend in science lessons per week. In the United States, the percentage of students receiving science instruction at school at least once a week was 5 percentage points higher among advantaged students than among their disadvantaged peers (96% of advantaged students vs. 91% of disadvantaged students). This compares to an average difference of 3 percentage points across OECD countries (Table I.6.15). In addition, advantaged students in the United States tend to receive about 50 more minutes of science instruction per week than their disadvantaged peers, compared to an average difference of 35 minutes across OECD countries, smaller differences in Estonia and Canada, a similar difference in Hong Kong (China), and a larger difference in Germany (Table I.6.15). These differences in science instruction time mean that, in the United States, for a school year of 36 weeks, the cumulative additional exposure to science lessons of advantaged students, relative to their disadvantaged peers, would amount to about 30 hours per year, compared to about 22 hours on average across OECD countries.

PISA 2015 further shows that, in many participating countries/economies, socio-economic differences in students' opportunity to learn science are associated to the incidence of stratification policies such as grade repetition and early tracking. For instance, while tracking may allow for a better match between students' interests and abilities and the subjects they study, it can also widen differences in students' exposure to subject-specific content, as subjects like science might be excluded from vocationally-oriented tracks or covered in less depth than in academic tracks. However, the prevalence of these sorting practices is low in the United States and most of the comparison counties.

Notes

1. Due to sampling and measurement error, the rank for the United States could be anywhere from 15th to 25th in science, 13th to 22nd in reading, and 29th to 31st in mathematics out of 35 OECD countries.

2. However, the coverage index in Viet Nam is only 0.56 and it is likely that a substantial portion of the 44% of students not eligible for the PISA survey perform below the baseline Level 2.

3. Indices used to characterise students' beliefs and attitudes about science were constructed so that the average OECD student would have an index value of 0 and about two-thirds of the OECD student population would be between the values of -1 and 1 (i.e. the index has a standard deviation of 1).

4. Only 6% of the difference between the United States and the OECD average can be attributed to students with vague or undecided career expectations.

5. A student is classified as resilient if he or she is in the bottom quarter of the PISA index of economic, social and cultural status (ESCS) in the country/economy of assessment and performs in the top quarter of residual scores among students from all countries/economies, after accounting for socio-economic status.

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3

Policies and practices for equity in education in the United States

This chapter discusses policies implemented to promote equity in four high-performance and high or improving equity education systems: Canada, Estonia, Germany and Hong Kong (China). Five specific policy directions applied, in various ways, across these diverse systems are identified. These policies provide ideas for the United States to consider as it aims to improve equity in its own education system and ensure that all students are given the opportunity to succeed in school and beyond.

INTRODUCTION

Equity in education is ensuring that all students, regardless of their background, have the opportunity to obtain a quality education and reach their full potential. Without an equitable education system, social and economic inequalities are perpetuated. Therefore, the goal for education systems is to ensure that all students acquire basic skills and that students' social or economic status has little impact on their opportunity to learn and their educational outcomes. Equity in education is about consistently ensuring high-quality education for all students in all schools. Equity does not always just mean equal: equitable education may also mean providing additional resources where they are most needed, for students with additional needs and for schools in disadvantaged communities.

For an education system, there is no significant trade-off between equity and performance. As PISA results have shown for many years, the strongest systems achieve high overall performance and strong equity as well. Equity and performance should be viewed as complementary rather than competing objectives. Seeing them as complementary objectives is important for understanding how to improve equity across education systems. An effective education strategy improves how school systems approach teaching and learning in classrooms. This requires sophisticated analysis of student learning needs, linked to actions which continually improve teaching and learning.

For too long, equity policy in school education has focused on what to do after students have fallen behind, or on how to provide additional financial resources for children from disadvantaged backgrounds. Both of these issues are important and will be discussed at some length in this chapter, but success for all students depends on a more strategic approach. In part, this is because focusing on children after they have fallen behind is expensive and requires more efforts to fix the problem than addressing the potential risks of disadvantaged students. Focusing too much on funding (an input focus) is inadequate for real change. A more strategic approach focuses on how to continuously improve teaching and learning in schools in a way that improves both equity and performance.

Policies to promote equity in learning are discussed below in a context of systemic reform. To help policy makers and education leaders improve equity in education based on the experiences of systems that exhibit both high equity and high performance, this chapter focuses on five policy pillars:

- **Policy 1. Education strategy to improve performance and equity**: This section examines a) the importance of strategic objectives and policies that emphasise equity throughout a system; and b) the steps that schools (and districts or regions) can take to improve equity and performance.
- **Policy 2. Rigorous and consistent standards across all classrooms**: This section focuses on consistent approaches to quality curriculum, assessment and pedagogy.
- **Policy 3. Improved teacher and leader capacity across the system:** This section showcases policies high-performing systems have adopted to develop more effective teachers and leaders.
- **Policy 4. Equitable access to resources:** This section examines how high-performing systems ensure that disadvantaged students and schools get additional resources to level the playing field and keep them from falling behind.
- **Policy 5. Targeting at-risk students and schools:** This section gives examples of how to address equity issues that systems often have to solve.

These five policy areas are all interconnected. It is important for education strategies to make the links between these areas to ensure an effective approach to improve equity and help at-risk students and schools, and also to avoid many common pitfalls and expensive and ineffective initiatives. It should also be emphasised that the above is consistent with a strategy that improves performance overall. The steps schools and systems need to take to improve performance are very similar – and often exactly the same – as those that improve equity.

WHAT THE UNITED STATES CAN LEARN FROM OTHER EDUCATION SYSTEMS

Education is a significant predictor of life outcomes for children in the United States. Students with higher-quality teachers and schools earn better salaries, have better health outcomes and are less likely to engage in crime or have children while they are teenagers (Chetty, Friedman and Rockoff, 2011; Heckman, 2008). Inequalities in education exacerbate inequalities in family background. Students in the United States are particularly diverse, both socially and economically, which means that the United States must intensify its focus on equity in education.

The United States has significantly improved equity in science achievement since 2006. Performance is less correlated to students' socio-economic status, and there are significantly more resilient students (students in the lowest national quarter of the PISA index of economic, social and cultural status (ESCS) who are in the top international quarter of performance) (Figures 2.6 and 2.9 in Chapter 2).

However, in 2015, the mean score of the United States in science is 496 (about the OECD average) and has not significantly improved over time (Figure 2.1 in Chapter 2). Many students in the United States are not meeting the baseline proficiency level as measured by PISA. In PISA 2015, about 20% of students in the United States scored below Level 2 in science literacy (Figure 2.3 in Chapter 2). This means that one in five 15-year-olds are below the baseline of proficiency at which students begin to demonstrate the skills that will enable them to participate effectively and productively in life. For students in the bottom quarter of socio-economic status, almost one in three are below this baseline (Table I.6.6a[1]).

Other education systems show that it is possible to have a high proportion of socio-economically disadvantaged students and still provide quality education to all students. Hong Kong (China), for example, has more than double the proportion of very disadvantaged students of the United States, but half the proportion of low performers in science. Of the students who took the PISA test in the United States, 11% are in the bottom two international deciles of socio-economic status, compared to 26% in Hong Kong (China) (Figure 2.10 in Chapter 2).

PISA consistently finds that high performance and high equity are not mutually exclusive. It is helpful to look at equity in combination with overall achievement (Figure I.6.6). Equity is not just about low variability in student achievement, but also about high achievement for students from all backgrounds. Successful education systems are those where inclusion and fairness in education and high levels of performance do not come at the expense of one another.

The United States has improved equity over the last decades, but too many of its students are still not meeting the baseline of proficiency (Figures 2.3 and 2.5 in Chapter 2). While the American school system is becoming more equitable, it still needs to focus on high quality across the board. It would be helpful for the United States to look at how other countries have achieved high overall achievement, without compromising equity, and to reflect on the policies and practices of these countries.

Four international education systems provide useful lessons to consider for the United States on how to maintain an equitable education system while also attaining high achievement overall: Canada, Estonia, Germany and Hong Kong (China). Both Canada and Estonia are examples of high equity and high performance with continuous improvement over time. Germany and Hong Kong (China) also provide a variety of lessons for the United States because of the diversity of their student bodies (see Box 2.1 in Chapter 2). The following case studies could give the United States ideas on policies and practices for equity. These systems demonstrate that it is possible to achieve strong learning outcomes while simultaneously maintaining a high degree of equity.

- **Canada**: Canada has many cultural and economic similarities to the United States, but it has a higher-performing and more equitable education system. The provinces of British Columbia and Ontario have particularly compelling results and provide lessons in whole-system reform and specific supports for vulnerable students and schools.
- **Estonia**: Estonia is a small education system that is high-performing and highly equitable. Very few students in Estonia perform below Level 2, and students of different levels of advantage are obtaining similar educational outcomes. Estonia provides lessons in how to create consistently high-quality education opportunities for all students.
- **Germany:** Germany is a large, federated education system with a student population as diverse as that of the United States. Germany is stronger than the United States at ensuring that students gain basic skills, with a greater proportion of students (including the most disadvantaged students) achieving Level 2 or above in science. Germany has improved equity in education over time, although it still faces a challenge of relatively high impact of students' socio-economic background on their performance. Germany can provide some examples to be considered by the United States on what kind of reforms could be introduced to improve equity in a complex federal education system.
- **Hong Kong (China):** Hong Kong (China) achieves excellence and equity in education despite its high proportion of very disadvantaged students. Fewer than one in ten students in Hong Kong (China) score below Level 2 in science, compared to one in five in the United States. Hong Kong (China) also has one of the smallest associations between student socio-economic status and performance. Hong Kong (China) therefore provides lessons on how the United States can systematically support high-need students and achieve excellence across the system.

Performance and equity in the United States

The United States has improved equity since 2006. The percentage of variation in science performance explained by students' socio-economic status has improved, and there is a greater percentage of resilient students across the country (Figures 2.6 and 2.9 in Chapter 2).

However, the United States is stagnating in overall performance in all subjects, and there are still many students (20%) that perform below Level 2 in science (Figure 2.3 in Chapter 2). Of students in the bottom quarter of the ESCS index, more than 30% do not meet a minimum bar of performance (Table I.6.6a). As noted above, Level 2 on the PISA science scale is considered a baseline of proficiency at which students begin to demonstrate the skills that will enable them to participate effectively and productively in life.

Systems demonstrating high or improved equity

The education systems of Canada, Estonia, Germany and Hong Kong (China) are all performing with higher overall outcomes than in the United States, although they are at different stages in their reform journey. Canada and Estonia are high-performing, high-equity systems that have improved performance over time while maintaining equity. Germany is a reforming system that has been successful in improving equity over time. Hong Kong (China) has a high proportion of disadvantaged students, but it has maintained one of the most equitable education systems.

Canada

Over the last decade, Canada has joined a group of high performers at the top of international rankings. PISA results since 2000 have revealed Canada's strong average results in reading, mathematics and science. Canada is also a high-equity country, where students perform well despite their socio-economic status. According to PISA 2015, Canada has a greater proportion of immigrant students than the United States (30% in Canada vs. 23% in the United States), but there is no gap in performance between immigrant and non-immigrant students in Canada, as there is in the United States (Table I.7.4a). It is important to note that Canada's migration policy is quite different from that of the United States, and Canada is targeting highly educated and skilled immigrants.

Canada is a federated system where education is a provincial responsibility. It is the only country in the developed world that does not have a federal department or ministry of education, though provinces collaborate closely through the Council of Provincial Education Ministers (OECD, 2011a). Despite this, the country has achieved excellent standards in educational attainment across its ten provinces and three territories. Canada's largest province, Ontario, educates about 2 million public school students (or around 40% of the country's total), while Quebec (1.2 million), Alberta (612 000) and British Columbia (540 000) have the next largest public school student populations (Statistics Canada, 2015). Ontario and British Columbia provide particularly interesting lessons for the United States, because these two provinces have initiated a series of reforms aimed at improving equity and excellence.

Ontario is a high performer on PISA and has strong equity outcomes (Figures 2.2 and 2.5 in Chapter 2). This is particularly interesting given Ontario's high proportion of immigrant students: 37% of students who do the PISA assessment in Ontario are first-generation or second-generation immigrants (Table B2.I.72). Starting in 2003, Ontario began a series of education reforms that have led to widespread positive results. In 2004, only 54% of students in grade 3 and grade 6 met provincial standards, and only 68% of high school students graduated within five years (Ontario Ministry of Education, n.d.). In 2016, 72% of students in grade 3 and grade 6 are meeting provincial standards, and 86% of students are receiving their high school graduating certificate within 5 years (Ontario Office of the Premier, 2016). This system-wide turnaround in student achievement was driven by sustained reforms targeting teacher quality, school improvement planning and coherent leadership at the school, district and provincial level.

British Columbia has had close to two decades of work building the capacity of teachers and school leaders to deeply understand student learning. In 2000, British Columbia released voluntary Performance Standards, which set in motion a greater focus on student learning progressions and formative assessment practices. The province also instituted specific policies to support immigrant and indigenous students. Both British Columbia and Ontario have emphasised systemic capacity building through inquiry-based collaborative networks which still exist today.

Estonia

With only 1.3 million people, Estonia is a very small country, but it could be compared to a large school district or a small state education system. Income inequality is less pronounced than in the United States, but there is still significant cultural diversity. After the collapse of the Soviet Union in 1991, Estonian became the only state language, whereas previously there were two official languages: Estonian and Russian. Many students still speak Russian at home, and while some Russian students study in Estonian-speaking schools, the majority attend Russian-speaking schools. This has led to two parallel school systems which produce different outcomes for students. Estonia is working hard to provide an equitable education for students at Russian schools with very limited spending on education.

Estonia is particularly strong at ensuring all schools offer very similar education opportunities. No matter which school students attend, they will receive a quality education (Figure 2.12 in Chapter 2). In Estonia, students from a low-income background have a much greater chance to perform at the top levels. In PISA 2015, almost half of the country's disadvantaged students were resilient, which means that they scored among the top quarter of students in all participating countries/economies despite the odds again them (Figure 2.9 in Chapter 2). Students in the bottom quarter of the socio-economic distribution in Estonia scored better than the average student in the United States (Table I.6.3a).

Estonia is an overall high performer in PISA 2015, achieving high performance in mathematics, reading and science compared to other OECD countries (Figure 2.2 in Chapter 2, and Tables I.4.3 and I.5.3), and it has been introducing policies that explicitly aim to promote equity in its education system. Between 2009 and 2012, Estonia increased its share of top performers in the PISA tests while, at the same time, reducing the proportion of low performers (OECD, 2014). This is commonly referred to as "raising the bar and closing the gap". Estonia is one of a very small number of countries to achieve both excellence and equality across the whole national system (Kitsing et al., 2016).

Estonia regained independence in 1991, following the collapse of the Soviet Union. The new government instituted a series of reforms to education in 1996, including a new curriculum for primary and secondary education, with standards and competencies. Education was made more accessible in the Soviet era, and the number of university graduates grew significantly. However, by the 1980s, being able to study at a university depended heavily on the type of school children were able to attend. Vocational schools were often seen as a dead end for students (Helemäe, Saar and Vöörmann, 2000). The 1996 curriculum was seen as a strong foundation, but it contained too detailed information that proved to be an extra burden for children, and a revised curriculum was created in 2002. Estonia joined the European Union (EU) in 2004, and paid more attention to standardised education and curriculum.

Recent reforms have included a new national curriculum in 2011 and a national education strategy for 2014-20. The new strategic objectives stress learners' individual abilities, the importance of competent and highly motivated teachers and school principals, lifelong learning opportunities for all and digital culture (Ministry of Education and Research, 2014).

Germany

Germany has the fourth-largest economy in the world and a population of over 80 million (IMF, 2016). After the United States, Germany hosted the second-highest number of migrants globally in 2015 (United Nations, Department of Economic and Social Affairs, 2016). When the first PISA results were issued in 2001, Germany learned that their 15-year-old students performed on a below-average level in reading, mathematics and science. Despite a long humanistic tradition emphasising the ethical foundations of education, Germany also learned that their system was one of the most inequitable among OECD countries. This "PISA shock" produced great controversy and debate that continues up to the present.

Since PISA 2006, equity in education has improved in Germany (Figure 2.6 in Chapter 2). Germany has also had a smaller proportion of students below Level 2 in science than the United States from 2006 to 2015 (Table I.2.2a). Compared to the United States, Germany serves its most disadvantaged students (those in the bottom quarter of the ESCS index) better. In Germany, these students are more likely to meet minimum standards and perform at the highest levels (i.e. resilient students) (Figure 2.9 in Chapter 2). Germany offers an interesting story of reform and is intriguing, because the broad contours of the system, especially regarding heavily tracked secondary schools, are relatively unchanged.

Hong Kong (China)

Hong Kong (China) maintains its own system of education under an Education Bureau. Population in Hong Kong (China) is around 7 million, and it has about 1 100 schools, which makes it comparable to a large district or state education system in the United States (OECD, 2011b). Hong Kong (China) has a large proportion of socio-economically disadvantaged students, with more than 26% in the bottom two international deciles of the ESCS index (compared to 11% in the United States) (Figure 2.10 in Chapter 2). Hong Kong (China) also has a large proportion of immigrant students, comprising 35% of 15-year-old students, according to PISA 2015 (compared to 23% in the United States) (Table I.7.1).

Hong Kong (China) is an interesting case study for equity in education because there is a large amount of income inequality. It ranks in the top ten most unequal economies (out of 145), based on its Gini index (a measurement of the income distribution of a country's residents) (CIA, 2013). Even with a large proportion of disadvantaged students, Hong Kong (China) still performs at the top of PISA for both excellence and equity (Figures 2.2 and 2.5 in Chapter 2). Compared to the United States, children from a disadvantaged background are less likely to fall behind their advantaged

peers. The equitable education system in Hong Kong (China) is also impressive because it was so recently reformed, after sovereignty changed to the Chinese government in 1997 (Lee and Manzon, 2014). Reforms largely began with curriculum and assessment and included abolishing public assessments after primary school, which led to more relevant school-based learning (OECD, 2011c). In the 2008/09 school year, the system was changed to make secondary education more inclusive, leading to more students attending a full 12 years of education (Lee and Manzon, 2014).

POLICY 1: EDUCATION STRATEGY TO IMPROVE PERFORMANCE AND EQUITY

Education strategy has a huge impact on the degree to which a system can improve equity. An education strategy covers all aspects of education policy and can thus direct all efforts to improve equity in school education. The experience of high-performance, high-equity systems highlights the importance of two aspects of effective strategies:

- strategic objectives that put a clear focus and urgency on equity, including the target population (e.g. indigenous students or all low performers)
- specific policies that show how teachers, schools and districts/states can improve equity.

Strategic objectives set a clear focus for all actors in a system. A strategic objective of improving equity should flow on to all actors, through their personal and organisational objectives, through their performance management and development programmes, and eventually through their daily practice.

A strategic objective on equity can be either quite specific or more general. British Columbia, for example, had an education strategy that emphasised improving education outcomes for Aboriginal students. This flowed on to policies that better documented and collected data on the learning outcomes of Aboriginal students, district-level and school-level strategies to improve Aboriginal students' learning, and a range of teacher development and targeted initiatives. Ontario, on the other hand, had a broader education objective to narrow the gap between its high and low performers. This flowed throughout the system in the school reporting process, teacher development and a variety of improvement initiatives.

As with many strategic objectives, the impacts are often implicit rather than explicit. When a strategic agenda has a consistent and strong focus on equity, it eventually has an impact on all aspects of the system. Both Ontario and British Columbia had a number of policies designed to enhance equity. Importantly, these initiatives were linked in a coherent strategy which greatly magnified their impact, and they clearly set out the steps that teachers, schools and districts needed to take to improve equity.

These steps are considered essential for improving equity in any school, district or system. In these school systems, the steps are not considered exclusively as equity initiatives, but rather as a broad strategic approach to improving the education performance of all students in the system. By pursuing this strategic approach, systems have boosted both performance and equity.

So what does this all look like? These systems – and virtually all high-performing systems – identify the steps for how schools and teachers (and in some cases school districts) improve. These steps invariably comprise a version of an inquiry-based improvement cycle. This improvement-cycle approach will be familiar to most educators and will resonate with organisational leaders across all industries.

While steps in the improvement cycle vary across systems, they generally include:

- **Needs analysis**: some form of needs analysis that involves a deep analysis of student learning. This can include both summative and formative assessments and other learning data.
- **Prioritisation**: a prioritisation of the most pressing student learning needs to be addressed.
- **Planning**: a planning phase that shows how teaching and school actions will improve to help these students.
- **Assessment**: collection of data on teaching practices that affect these students and how they change over time.
- **Monitoring**: evaluation and monitoring of changes in teaching and school practices and how these changes affect student learning.

These steps underpin a clear improvement process for schools, teachers, districts and regions. They come in different forms in different systems and schools. Some call them inquiry cycles, while others call them school improvement models. Some structure them as different formative assessment and improvement processes. In British Columbia, they are generally referred to as a Spiral of Inquiry, reflecting an emphasis on formative assessments in a number of districts.

In Ontario, the steps reflect the improvement process for schools and school boards that is inherent in planning and reporting requirements. In all of these systems, the steps underpin teacher and leader development, professional learning, and both in-school and out-of-school development programs.

While the details of all of these steps and improvement models are outside the scope of this paper, crucially for this analysis, they reflect what is required to improve equity in a system. The steps increase the focus on the following issues:

- **Student learning**: The needs analysis of student learning puts a much greater focus on both the state of student learning and how students are learning, including how they are responding to different teaching practices and differences in how schools operate. When done well, this is much more than an analysis of school scores in standardised assessments (although that can be important). It puts an emphasis on formative assessment – where student learning is currently and what students are ready to learn next. This requires a deeper understanding of student learning, student progress in different areas and how students are responding to different teaching practices.
- **At-risk students**: Around the world, much is made of the dislocation of at-risk students, who have lower levels of classroom participation and gradually become removed from active learning. Many systems struggle with students who, for example, reach different levels of secondary education without the requisite skills to succeed. In high-performance, high-equity systems these steps create a continual focus on student learning that, in turn, continually increases the focus on both summative and formative assessment as well as methods that help educators understand how to improve the learning of at-risk students. This directly addresses the above problems and puts in place the foundation necessary to help at-risk students.
- **Equity goals:** A prioritisation process increases the focus on equity by encouraging schools and other organisations to take effective actions. Schools in high-performing systems often have the autonomy to choose the area they want to focus on for improvement. Given the moral imperative to help underperforming students, this regularly sees schools prioritising students who are falling behind or not progressing as they should. The mix of autonomy and moral imperative to help students in need increases ownership of the improvement process, and that drives improvements in equity. In this sense, these steps create a systemic bottom-up approach to equity: schools own the process and choose where to focus their energies. This contrasts with many equity policies that are top-down in nature (such as increased funding for at-risk students and programmes for students who are falling behind).

The strategic focus on the steps schools and teachers should follow to boost learning builds the foundational elements for improvement. Education policy debate often emphasises the use of data and the need for schools and teachers to focus on individual learning needs, especially those of students most in need. An inquiry-based improvement cycle illustrates what this means in practice in systems that achieve both high performance and high equity. The cycle is a central element of a system-wide strategy aimed at all students and schools, but it has a particular impact on equity. The strategy does not replace a focus on providing targeted equity policies or consistent quality education to all students. But it provides a foundation that not only fosters improvements in equity and performance across a system, but enables other equity initiatives to have a significant impact as they are implemented in schools that are already undertaking fundamental steps to improve teaching and learning.

POLICY 2: RIGOROUS AND CONSISTENT STANDARDS ACROSS ALL CLASSROOMS

One of the main ways to improve equity is to ensure consistency across schools and classrooms. That way, students in a disadvantaged school will not receive a substantially different education than students in an advantaged school. A key element is the degree of common practice across all schools within a system. Two types of policies have a mediating impact on the performance of students of different socio-economic and immigrant backgrounds: policies which affect access to educational resources and policies which affect the stratification of students (OECD, 2016a). Systems aiming to improve equity must consider what should apply strictly across the system and what can be left more to the individual choice of different schools.

Many systems, for example, have central standards or curriculum, but give schools ample autonomy to shape the central curriculum for their own school needs. It is important to consider the relationship between the requirements for common practice – the main things every school must have in the context of an autonomous school system – and equitable education for all students.

One key goal for school systems is to ensure that all students are meeting robust curricular standards, no matter which school they attend. Having clear and shared standards can help to ensure that every student is prepared for higher education or career. This does not mean that schools should offer limited curricular choices, but that each school meets the same minimum standard. Many high-performing systems, particularly in Estonia, allow schools great autonomy. However, these systems also tend to have a central, rigorous curriculum (or set of standards) that sets a framework for school-based curricular choices.

Box 3.1 **Opportunity to learn**

Decisions on curriculum and standards have a large impact on student achievement. Opportunities to learn are defined by exposure of students to different types of curricular content. PISA asks students about the degree to which they encountered various types of curricular activities during their schooling, how familiar they are with certain formal content and how frequently they are exposed to different concepts. There are great variations between and within countries on these measures. However, in high-performance and high-equity systems, the socio-economic status of students makes little difference in their opportunity to learn.

Source: OECD (2014), *PISA 2012 Results: What Students Know and Can Do (Volume I, Revised edition, February 2014): Student Performance in Mathematics, Reading and Science*, http://dx.doi.org/10.1787/9789264208780-en.

School autonomy is best supported by a standardised policy, including curriculum, standards and shared instructional materials. In education systems where school principals hold greater responsibility for school governance, students score higher in science. This relationship is stronger in school systems where the percentage of students whose achievement data are tracked over time and posted publicly (OECD, 2016a).

Estonia is a good example of high school autonomy with shared guiding standards. Even before joining the European Union in 2004, the country had begun to adopt policies of standardisation, accountability and quality assurance for education. Joining the European Union has led Estonia to pay more attention to strategic planning and setting challenging goals with indicators at the state level. Estonia's schools follow a national curriculum that helps ensure that all students receive a similar education, no matter which school they attend. Schools in Estonia have a high level of autonomy, and each school creates its own curriculum based on the national curriculum.

Estonia's school system was decentralised in the early 1990s, devolving responsibility for the local school system. Estonia's school principals have very high levels of autonomy, including the authority to hire and fire staff, and negotiate working conditions and job contracts, with fully delegated powers to make decisions about school finances, educational priorities and development plans for the school (Kitsing et al., 2016; Santiago et al., 2016). Studies indicate that decentralised education systems like Estonia's provide more equal opportunities for students to experience high-quality education (Oppedisano and Turati, 2015).

After regaining independence in 1996, Estonia created a new national curriculum which empowered schools to plan their own schemes of work and design learning activities so that students would meet the national standards. An external evaluation process was established to monitor implementation. National student assessments occurred at the end of high school, and sample-based assessments were added in grade 3 and grade 6. The assessments are used in a formative manner, to inform students about their progress, to direct the content of the curriculum, to guide the learning process and to provide feedback to schools. Individual school results are not published, but an average is publicly displayed. Each school receives detailed information about its results to inform school improvement. The assessments in grade 3 and grade 6 are done by sample instead of testing all students. Students in grade 9 take three exams as part of the completion of lower secondary school, but individual school results are not published.

Like Estonia, Canada also has shared standards across schools, within provinces. There is no national framework, but part of Canada's success might be ascribed to the establishment of province-wide curricula. During Ontario's reforms, high standards and expectations included a standards-based curriculum related especially to literacy and numeracy, a transparent standard of performance and independent assessment of student achievement by the Education Quality and Assessment Office (Fullan and Rincon-Gallardo, 2016).

One step taken by Germany has been to provide greater coherence in its system by agreeing to common educational standards across its 16 states (*Länder*). This reform was undertaken by the Cultural Ministers Conference, beginning in 2004. The standards apply to all public school students, and they have led to increased academic content in Germany's vocational schools. Germany has also introduced standardised testing of students at grade 3 and grade 8. The *Länder* choose whether they will test students in German or mathematics, or both subjects. Testing is done for diagnostic purposes, and test results are generally not released to the public. The assessments are used more for improvement than for strict accountability.

Box 3.2 **New pedagogies for deep learning**

Leaders from Ontario and other systems around the world are looking at ways to shift from traditional learning to deep learning. This involves new pedagogical practices, which include new learning partnerships, deep-learning tasks, and digital resources and tools – partnerships between and among students and teachers that tap into the intrinsic motivation of all learners. The learning tasks, based on real world problem solving, are enabled and enhanced by technology. A shift to deep learning has implications for curriculum, assessment and strategy (Fullan and Langworthy, 2014).

Advocates of deep learning are currently gathering evidence on global research questions, many of which pertain to whether deep learning improves equity and the ability of at-risk students to increase achievement. For example, a hypothesis of deep learning is that a series of competencies will improve each student's ability to excel in school and career. There are Deep Learning Progressions which assess students' current levels in each of the six competencies: collaboration, creativity, critical thinking, citizenship, character and communication (NPDL, n.d.).

Setting equity goals and monitoring progress with school and student assessments

Data on student learning can be strategically used to identify students or schools at risk of not meeting minimum standards. These data can be used to inform interventions and policies to improve equity. Setting specific goals for improving equity can help motivate systems to create a sense of shared responsibility. In Estonia, for example, the principle of equity was written into law and approved by the Estonian Parliament in 1993. Germany set up a highly respected Institute for Quality Assurance that provides research on schools similar to that of the National Assessment of Educational Progress in the United States.

In the beginning of Ontario's reforms, the province built a database for assessments and tracking data. This also helped to identify strong case studies to share practice (e.g. which schools are best supporting English-language learners, which schools are reducing dropout). During its reform period, Ontario set ambitious goals. There were only a few specific goals, to maximise the focus of the system on meeting them. One of those broad goals was to close the achievement gap between advantaged and disadvantaged students. This was part of the core agenda that motivated teachers and school leaders in a shared vision of success in Ontario. Having "closing the gap" as one of a small number of goals ensured that policies all served the purpose of improving equity. Ontario's goals ensured that there was system cohesion, with policies and units all serving the same integrated purpose. Having shared goals and monitoring them with student data help to create shared language and shared accountability across the system (Fullan and Rincon-Gallardo, 2016).

Estonia has national student assessments designed to give students, parents, schools and the government objective and comparable feedback related to the learning goals in the national curriculum. Estonia uses central student assessments more for formative purposes than for summative purposes, using them, for example, to identify aspects of instruction or the curriculum that could be improved (OECD, 2016b). Estonia emphasises internal assessment and action planning as central parts of system evaluation.

Box 3.3 **Inquiry and formative assessment focus in Canada**

Ontario and British Columbia have emphasised formative assessment and collaborative inquiry as ways to build educators' capacity to monitor their impact on student learning. In British Columbia, the focus began close to two decades ago, with the introduction of Performance Standards. These standards were learning progressions for students that helped educators with formative assessment practices. This type of classroom-based assessment is the main way teachers and school leaders evaluate whether or not they are making progress in improving student learning. Deeply understanding where students are at in their learning helps teachers and schools to diagnose issues for students who are falling behind and monitor their progress as they trial instructional interventions.

To help teachers and school leaders implement these voluntary Performance Standards, the British Columbia Ministry of Education funded collaborative networks where school teams followed a structured inquiry process to consider how to get the standards working throughout their schools. School districts also created their own professional development opportunities, training school leaders in formative assessment and messaging its importance.

"This bedrock set of practices has created a profession that can talk about growth in student learning in key areas. (This is) a kind of evidence literacy that we do not find in many other English-speaking jurisdictions."

– Linda Kaser, Founder of Networks of Inquiry and Innovation

Monitoring of schools and districts through external or self-assessment is a common practice in high-performing systems. For example, Ontario's school boards (similar to US school districts) are required to submit an annual Board Improvement Plan for Student Achievement. The provincial Ministry of Education created specific guidance for school boards in their planning, which helps to ensure that all boards have evidence-based student achievement plans. These plans serve as one way for the province to monitor the consistency of education across school boards and schools. This is very much in line with the 2015 Every Student Succeeds Act in the United States, which aims to give more freedom to individual states to determine how to assess student performance. In Ontario, the guidance to school boards and the review of each of their plans helps with quality assurance. The Ministry also conducts visits to school boards twice every year, or three times if a board is underperforming.

Estonia has a national evaluation and assessment framework for monitoring education each school year. The Ministry of Education and Research establishes the priorities of national inspection for each school year, and county governors carry out thematic inspections related to these priorities. Approximately 10% of the total number of schools are inspected each year, and the inspection takes up to eight days. After an inspection, a report is issued with feedback for the school, and there may be a requirement for the school to improve in specific areas. The results are commonly used by schools in their ongoing improvement plans (Estonian Ministry of Education and Research, 2012). In Estonia, supervisory control of schools is exercised by the governing body (either the municipality or the state) but it is not specifically regulated by legislation.

Prior to 2006, Estonia had regular external inspections of every school. In 2006, Estonia ceased these independent inspections of schools and moved to mandatory self-evaluations. To support implementation of this new evaluation system, state counselling was guaranteed to every educational institution from 2006 to 2013. The purpose of the counselling was to enhance the objectiveness of evaluation, deepen educational institutions' awareness of their situation and offer additional information for comparison. The counselling also aimed to support and develop the conduct of internal evaluation, the preparation for evaluation and the development of a culture of evaluation.

POLICY 3: IMPROVED TEACHER AND LEADER CAPACITY ACROSS THE SYSTEM

Teachers have the largest in-school effects on student achievement (Hattie, 2003). Teachers are a key resource in education, and an important component of equity policy is to ensure the quality of teachers in general and to allocate excellent teachers in disadvantaged schools and classrooms. How teachers are attracted to the profession, developed and supported has a strong impact on the performance of students and schools. It is therefore important to ensure that teachers in the neediest schools have the skills, resources and support to ensure student learning.

Highly equitable systems ensure that all schools have quality teachers and school leaders, and that teachers and leaders at disadvantaged schools have particular development opportunities to meet the needs of all students.

Make the teaching profession more attractive and selective

Many education systems have trouble attracting high-quality teachers, especially in disadvantaged areas. When teaching shortages occur, schools in low-income areas are most likely to be affected and systems may have to lower standards for entry into the profession. Teacher turnover may also be higher in these schools, leading them to have the least experienced teachers. In fact, disadvantaged schools in the United States report a far greater negative impact from teacher shortages than advantaged schools (Schleicher, 2014). This gap is one of the largest among OECD countries. Canada, Estonia, Germany and Hong Kong (China) share problems similar to those of the United States in making the teaching profession more attractive. Systems that demonstrate high performance and high equity have policies to increase the attractiveness of the teaching profession and to attract the most skilled teachers to the most disadvantaged schools.

One of the primary ways to recruit stronger teachers is to raise teacher salaries. Higher teacher salaries (relative to those of similarly educated workers) are associated with higher teacher skills in numeracy and literacy (Hanushek, Piopiunik and Wiederhold, 2014). Canada, Germany and Hong Kong (China) ensure relatively high salaries for teachers. The ratio of salaries for lower secondary teachers (with typical training) after 15 years of experience to per capita GDP is 1.63 in Hong Kong (China), 1.53 in Germany and 1.50 in Canada, while the ratio is 1.16 in the United States (Table II.6.54[2]).

Financial incentives are not the only factor that attracts teachers to disadvantaged schools. Teachers need to feel supported and successful. Combining support with incentives for new teachers is important. It is also important for teachers to feel valued so that they stay in the profession and in the school. Germany hires teachers as public servants, who are guaranteed relatively high salaries and good working conditions. Because of this, Germany is able to attract high-quality teachers to all schools. For example, a 2014 study showed that teachers in Germany may have some of the

highest mathematics skills of any teachers in the world (Hanushek, Piopiunik and Wiederhold, 2014).

Estonia deals with issues similar to those of the United States in terms of attracting new teachers to the profession. Teaching is not considered a valued profession in Estonian society, and there are shortages of mathematics and science teachers. There has been a significant increase in teachers' salaries since 2000, but they are still lower than the OECD average (OECD, 2016b). Estonia is making efforts to align teachers' salaries with the earnings of full-time, full-year workers with tertiary education by 2020 (OECD, 2016b).

Estonia is working to target issues of teacher quality with the following initiatives (OECD, 2016b):

- In 2014, it introduced a career structure based on professional standards and the acquisition of competencies for all teachers.
- By 2020, it will fully align teachers' salaries with the earnings of full-time, college-educated workers.

Improve teacher preparation and development

Given the complexity of teaching, especially in disadvantaged schools, teachers need high-quality development opportunities. It is important for systems to ensure that all teachers – not just teachers in privileged schools – get access to quality professional learning opportunities. Systems can support consistency of teacher quality by encouraging collaboration to share practice and giving guidance to all schools that provides a consistent standard for teacher development. System guidance is particularly important when schools are highly autonomous, because the guidance that the system gives is the main factor in creating consistency of outcomes. The United States can learn from Canada and Estonia how to create more consistency in teacher development through standards, guidance and collaboration, without reducing school autonomy.

According to the OECD Teaching and Learning International Survey (TALIS), the collaborative cultures in Estonia's schools are among the highest in participating countries (Übius et al., 2014). In 2013, Estonia adopted new professional standards for teachers in order to develop formal and continuous teacher-training plans and to assess future teachers' readiness to enter the profession (OECD, 2016b). There is a new continuous professional development system for teachers which comprises national qualification requirements, professional standards for teachers, a central in-service training system aligned to these professional standards and non-mandatory in-service training hours.

Ontario created more consistency for teacher development with a Teacher Development Framework, a non-binding framework available for all schools to use to plan teachers' professional development. The framework covers induction, annual learning plans and teacher appraisal (Fullan and Rincon-Gallardo, 2016). Ontario also created a mandatory New Teacher Induction Program, which provides orientation, mentoring and professional learning opportunities specific to the needs of new teachers (Fullan and Rincon-Gallardo, 2016). Ontario also launched the Building Futures program in 2004 to assist teacher candidates to understand the core education priorities of the province (Fullan and Rincon-Gallardo, 2016). This helps to ensure that all new teachers have basic skills, no matter which school they are teaching at.

Improve school leaders' ability in all schools

School leadership has the second-largest impact on student outcomes after teacher quality (Leithwood, et al., 2004). School leaders play a crucial role in determining school and classroom conditions that affect student learning. Principals not only lead teaching and learning, but are also responsible for management of the school and for engaging and working with the community (Australian Institute for Teaching and School Leadership, 2014). Principals set the vision for their schools, conduct strategic planning and resourcing, and foster the school's learning culture.

Disadvantaged schools, especially schools in remote or isolated areas, often have trouble recruiting and retaining top-performing school leaders. Leaders at these schools also need specialised skills to deal with issues that are not present in more advantaged locations. The system can support these leaders by creating more consistent leadership quality across schools and by providing disadvantaged schools with additional support.

Ontario has deployed guidance and support to school boards to ensure that all of them are effectively improving the capacity of school leaders. In 2006, the Ministry of Education created the Ontario Leadership Framework to create a shared vision of what effective leadership looks like across the province. The framework is not mandatory, but was adopted by every school board to frame leadership development policy.

The Ministry of Education launched the Ontario Leadership Strategy in 2008 to complement overall efforts to drive further improvements in student achievement. The strategy aimed to attract the right people to leadership roles and to develop leadership capacity across the system. It targeted all of Ontario's school boards by providing them with funding

and guidance to develop Board Leadership Development Strategies, which had the specific goals of recruiting and developing effective school leaders.

Ontario has also created a Principals' Qualification Program, which all principals and vice-principals are required to complete (Fullan and Rincon-Gallardo, 2016). This programme ensures that all principals in all schools have met a minimum standard of skills and knowledge.

There is also a mentoring program for all new principals which helps match them with an experienced mentor. This helps share knowledge across the system and ensures that schools with new principals have extra support. This is important, because disadvantaged schools are often more likely to have newly qualified principals.

Estonia has also had recent policies aimed at improving the capacity of school leaders. The country implemented several special leadership programs in the past decade which have been supported by the European Social Fund. Estonia also developed a principal competence model in 2013, and in-service training of principals has been designed based on the competence model. A key part of these initiatives is a trilateral agreement between the Ministry, universities and representatives of local authorities. These groups all agreed to use the principal competence model in designing courses for principals and for principal talent identification and selection.

Foster collaboration among all schools

Collaborative networks among schools can help to reduce the effects of school segregation and ensure more consistency of practice throughout a system. Collaboration can happen among teachers or leaders, or both.

In the early 2000s, the British Columbia Ministry of Education funded school networks to aid the adoption of new provincial Performance Standards. These cross-school networks, now called the Networks of Inquiry and Innovation, are structured around a collaborative inquiry approach, which takes school leaders and teachers through a process of assessment, development and evaluation. These networks have been influential in shaping professional learning within schools and between schools. Participants have strong shared language around student learning and are able to distribute effective practices, such as formative assessment, across many schools over time (Jensen et al, 2016).

Since 2000, some 500 schools have participated in networks that bring teachers and school administrators together from districts across British Columbia (Halbert and Kaser, 2013). Educators participate in the networks voluntarily, and they base their work on the shared goal of improving the quality and equity of education across the province (NOII, n.d.). The majority of participants are teachers, but each team has one formal school leader (principal or vice principal), and support staff are also welcome. School teams create an inquiry question and meet with the network after school three times during the year to share strategies from their inquiry and what they have learned. Each school is asked to write a short case study of their inquiry at the end of the year (Katz et al., 2008). Participating schools receive a small grant from the Networks of Inquiry and Innovation (CAD 300 to CAD 1 000), which is used to purchase resources, fund release time or pay for travel to meetings (Kaser and Halbert, 2014).

POLICY 4: EQUITABLE ACCESS TO RESOURCES

It is not just the amount of resources that matter for quality education, but how those resources are distributed. The United States has particular concerns about school funding equity, with schools in advantaged areas receiving more funding than those in disadvantaged areas because of local funding systems (for further information, see Chapter 6 in OECD, 2016a). However, per-pupil funding is not the only resource systems should consider when they aim to provide a more equitable education system. Access to early childhood education, after-school tutoring and counselling all make a difference in learning outcomes for students. High-performing and high-equity systems ensure that these resources are available to the students who need them most.

Early childhood education

Participation in high-quality pre-school education prevents children from relatively disadvantaged backgrounds from falling behind their peers in terms of educational progress during their early years. This has a lasting impact on their learning. Students who attend early childhood education perform better on PISA than those who do not. At the system level, there is also a relationship between the proportion of students who have attended pre-primary education for more than one year and the overall performance of systems (Schleicher, 2014).

In Estonia, Germany and Hong Kong (China), rates of early childhood education are higher than in the United States (as is the OECD average). Across OECD countries, around 5% of 15-year-old students reported that they had not attended pre-primary school at all: this figure is 15% in the United States, while it is around 1% in Hong Kong (China) and Germany, 2% in Canada and 5% in Estonia (Table II.6.50). The United States also has a significant gap in the year of attendance between the top and bottom socio-economic quarters (also higher than the OECD average) (Table II.6.51).

Estonia focuses on ensuring that everyone has access to a very similar education, regardless of their background. Early childhood education is government-subsidised, and families of the lower social-economic background can apply for discounts or full release of fees. Most children are enrolled in early childhood education by age 3. There is a standard curriculum for early childhood education, ensuring a minimum standard of quality across pre-schools. Therefore, the quality of early childhood education does not depend on family income in Estonia, as it does in many parts of the United States. In Estonia, compulsory primary education begins at age 7, but a great majority of 4-year-olds (91%) and 3-year-olds (87%) were enrolled in early childhood education in 2013 (OECD, 2016b). This is above the OECD average and well above the rate of early childhood education enrolment in the United States. Around 96% of these 3-year-olds and 4-year-olds in Estonia attend public early childhood education institutions (OECD, 2016b).

Canada has low early childhood education access, but is currently working to improve enrolment rates. For example, in 2010, Ontario passed a law to provide full-day kindergarten integrated with day care to all 4-year-olds and 5-year-olds.

Financial resources

It is important for systems to allocate resources where they can make the greatest difference. Equitable distribution of resources across schools predicts education system performance. PISA 2015 found that 31% of the variation in science performance across OECD countries can be explained by the degree of equity in the allocation of schools' educational resources between socio-economically advantaged and disadvantaged schools. The United States spends more per student than Canada, Estonia and Germany (Schleicher, 2014). However, disadvantaged schools in the United States are more likely to be concerned with educational resources than advantaged schools – more so than Canada, Estonia and Germany.

Over the past half-century, most provinces in Canada have moved from local education financing to provincial-level financing, creating more equitable education systems. The provinces transitioned provincial-level financing from local boards raising taxes, which is similar to current funding methods in the United States (Fullan and Rincon-Gallardo, 2016). In 1950, 64% of education costs were paid locally, and 36% by the provinces. By 1997, eight of the ten provinces reformed to take complete responsibility for funding (OECD, 2011c). Funding from the provinces to school boards/districts includes equalisation funding, which is used to ensure that poorer board/districts have equal funding to others (OECD, 2011c).

Health and well-being support for all students

Providing a continuum of supports for all students can help close the gap between advantage and disadvantage. Providing these types of supports can help students with attendance, behaviour, achievement and socio-emotional skills. This support might involve counselling, parental assistance or healthcare. Estonia's schools have offered a free hot school lunch for all primary and lower secondary school students since 2006, as well as medical and dental services (Kitsing et al., 2016).

Extended school day

Estonia also has long-day groups which were established to ensure that students are supervised after the school day as well as given pedagogical guidance and instruction during this time (Republic of Estonia, 2010). The long-day groups are free for students. Schools in Germany traditionally have sent students home for lunch in the middle of the day, and they did not return to school. The short school day has meant that schools have less time to address the particular needs of specific populations, such as immigrant youth and students from working-class families. To try to enhance equity and to foster women´s employability, Germany has been expanding full-day schools (*Ganztagschulen*). Currently, 56% of pupils in Germany have access to such full-day schools.

POLICY 5: TARGETING AT-RISK STUDENTS AND SCHOOLS

To achieve greater equity, systems need to proactively intervene to support students and schools that are at risk of failing or falling behind. This often requires strong monitoring and data analysis to predict which students or schools may need extra support. There may be groups of students that need particular interventions, such as immigrant students who require additional language supports. High-equity systems are strategic in planning for and targeting these students and schools.

Box 3.4 **Disaggregating data to target disadvantage in British Columbia**

Some systems have created data systems to better identify students with at-risk profiles. The disaggregation of data for specific subgroups can be helpful to identify issues that may not be obvious from the averages.

In British Columbia, information about student learning has been disaggregated between Aboriginal and non-Aboriginal learners for more than a decade. This information is available in a report entitled *Aboriginal Students: How Are We Doing?* (British Columbia Ministry of Education, 2015). The report enables strategic planning at the district level as well as individual school growth planning and inquiry. These reports have showed steady growth and closing of gaps, but the province acknowledges that there is a still a lot of work to do.

Strategies for at-risk students

As part of its reforms, Ontario designed a province-wide strategy to help students in grade 7 to grade 12 who need additional support to further their learning needs. The primary goals of the strategy are to target at-risk students and increase the rate of high school completion. The Ministry of Education supports the strategy by providing guidance and funding to schools and districts to help them develop intervention strategies (Ontario Ministry of Education, 2014). For example, the Ministry provided funding to school boards to employ a Student Success Leader and to secondary schools to employ a Student Success Teacher in every secondary school to co-ordinate the strategy at the school level. These Student Success Officers help districts, schools and teachers to identify at-risk students and formulate teaching interventions. Their role includes a focus on literacy, credit recovery, tutoring and re-engagement in school (Fullan and Rincon-Gallardo, 2016).

High schools in Ontario now have a Student Success Team to drive strategy implementation, comprising a principal, a Student Success Teacher, a guidance counsellor and a special education teacher (Ontario Ministry of Education, n.d.). The Student Success Strategy provides professional learning for school leaders and teachers and focuses on tracking and monitoring student achievement data (Ontario Ministry of Education, 2016).The provincial government attributes its success in attaining an 85.5% rate of graduation within five years to programmes and initiatives delivered through the Student Success Strategy (Ontario, Office of the Premier, 2016).

In British Columbia, the Ministry of Education provides funding for additional language support for immigrant students at risk of falling behind. The funds must be accompanied by an annual instructional plan prepared by the school with guidance from a specialist. Schools are also required to provide training for teachers and additional out-of-class support for students (OECD, 2011c).

British Columbia has also had success in a long-term strategy to better support Aboriginal students and their schools. Aboriginal Education Enhancement Agreements have been a practice supported and facilitated by the Ministry in British Columbia since 2000. Enhancement Agreements are working agreements between a school district, all local Aboriginal communities and the Ministry of Education that are designed to enhance the educational achievement of Aboriginal students (British Columbia Ministry of Education, n.d.). This practice, when done well, has focused attention on collaboration between school districts and the Aboriginal community. The agreements have drawn the attention of educators to ways in which they can support learning for Aboriginal youth.

Reducing grade repetition

Grade repetition is one of the mediating factors on the performance of students of different socio-economic and immigrant backgrounds and is associated with low equity in PISA (OECD, 2016c). Grade repetition occurs when schools determine that students are so far behind that they would benefit from repeating the same grade level the next year. The decision to hold a student back represents a failure of the system to effectively monitor and intervene early to improve that student's learning. Grade repetition may not benefit all students, and it is costly (Brophy, 2006; West, 2012). In the United States, about 15% of students repeat a grade before age 15, slightly above the OECD average. After accounting for variables

including performance, motivation and behaviour, socio-economically disadvantaged students are more likely to repeat a grade in the United States.

To effectively intervene with student learning issues and reduce grade repetition, systems can provide early and timely support to struggling students. This requires teachers who are able to diagnose student learning issues, create an intervention plan and monitor progress. Students at risk of falling behind can also benefit from additional instruction opportunities that help them catch up.

In Estonia, grade repetition is among the lowest in the OECD, with only 4% of students repeating a grade at least once before age 15. Estonia revised education laws in 2010 to help enforce mandatory school attendance and reduce dropout. This law mandates a regular update to databases to ensure early detection of students with school absence problems. The law also improves delivery of support services in schools, such as career counselling and guidance, social pedagogy, psychology and speech therapy (OECD, 2016b).

Estonia's national education plan in 2007-13 emphasised the early diagnosis of any special educational needs among young children. Early intervention was offered to children in early childhood education. Students with special education needs were monitored closely when they entered the school system and additional personalised support was provided for each student (Kitsing et al., 2016).

Estonia also established county-level study counselling centres to create the preconditions for early identification of learning and behavioural problems. The counselling covers special-needs education, speech therapy, psychological assistance and social pedagogical counselling. Regional study counselling centres are financed by the state and provide social pedagogical counselling and support services to children, students, parents and educational staff. Rural schools and pre-school childcare institutions use the services of study counselling centres more frequently than others, reducing inequality caused by the place of residence (Kirss, 2011).

Box 3.5 **Estonia's emphasis on metacognitive skills may help disadvantaged students**

A growing body of research emphasises the importance of students developing metacognitive skills. These skills allow students to self-regulate learning, understand when they are struggling to understand a concept and to develop strategies to improve study (Hattie, 2008).

Analysis of international comparative studies indicates that Estonia's teachers structure their lessons clearly and organise learning activities to develop higher-order thinking, which may explain the high performance of Estonia's students in PISA assessments (Henno, 2015). In addition, students in Estonia have well-developed metacognitive learning strategies (such as planning, monitoring and evaluating their work), which are important supporters of high achievement (Säälik, 2015). In Estonia, students' awareness of metacognitive learning strategies explains 30% of the differences between schools and 13% to 15% of the differences within schools (Säälik et al., 2015). This is clear evidence of the value that metacognitive skills add to students' learning (Kitsing et al., 2016).

Targeting low-performing schools

In Estonia, about 20% of students speak Russian and attend Russian-language schools. These schools follow the same curriculum as Estonian schools, but they have achieved considerably lower results in past PISA assessments. They have been targeted for specific reform. Decentralisation may have contributed to the lower performance of these schools (Carnoy et al., 2015). For example, the freedom to make decisions at school level allowed Russian-language schools to maintain the Soviet-period approach to teaching and learning. These schools essentially operated in a different school system, participating in different professional development activities and not collaborating with Estonian schools (partially because of the language barrier). While the resources for all schools are equal, and Russian-language and Estonian-language schools enjoy equivalent autonomy, the teaching quality at Russian schools was lower. This is partly because reforms and new evidence about teaching was quickly distributed in Estonian schools, but did not take great effect in Russian schools (Kitsing et al., 2016).

Estonia responded to these equity challenges by implementing several programs for improving the efficiency of Russian-language schools. Special counselling centres were established to guarantee the quality of instruction and the development of teachers. Additional study materials were prepared for Russian-language schools that aligned more closely to the topics being taught in Estonian schools. Teacher in-service programmes and teaching materials were renewed, which helped to increase the professionalism and motivation of Russian school teachers. This also supported

their Estonian-language competence, which had the additional effect of making it possible for teachers from the Russian schools to participate in professional development with teachers from the Estonian schools.

A specific Estonian-language immersion program was launched in 2000 to help integrate Russian students into Estonian society starting in grade 1. At the beginning, the programme was introduced in four Russian-language schools. Their number increased gradually and, by 2010, language immersion classes had been opened in 34 schools, about 50% of the Russian-language schools. The schools participating in the programme are characterised by multilevel collaboration between teachers, students, schools and homes. The schools and local governments in the programme have formed a co-operation network that meets regularly, where participants share their best practices.

Research carried out in Estonia indicates that teachers of language immersion classes value the learning outcomes of their students more highly than teachers of classes where the language of instruction was only Russian. The language immersion programmes are built on modern pedagogical methods, and teachers involved in them also learned effective ways to create a favourable learning environment and new modes of teaching (Sau-Ek et al., 2011; Kukk et al., 2012; Language Immersion Centre, 2014). In addition to improving the professionalism of teachers and changing the school culture, there was also a focus on development for school leaders in Russian-language schools, providing them with special professional development courses. Best practices of Russian-language and Estonian-language schools have been shared by the school leaders through site visits.

Ontario also had success with reforms on school interventions. The Ontario Focused Intervention Partnership (OFIP) was launched in 2006/07 to offer targeted support to low-performing elementary schools. Initially OFIP schools were defined as having 33% or fewer students achieving low levels for two of the previous three years. But from 2009/10 to the present, these schools have been defined as having 50% or fewer students at that standard for two consecutive years. OFIP was non-punitive and focused on capacity building. Intervention strategies were created in conjunction with Ontario's Literacy and Numeracy Strategy that included needs assessment, support, co-development of an action plan, participation in school-based learning communities and learning from other schools through formal and informal networking (Fullan and Rincon-Gallardo, 2016). Secondary schools were supported by the Student Success School Support Initiative for the lowest achieving 20%, or about 180 schools. Activities primarily involved building the capacity of the principal and teachers as instructional leaders in order to enhance instructional practices resulting in improved student achievement (Fullan and Rincon-Gallardo, 2016).

CONCLUSION

Policies and practices presented in this chapter offer ideas that the United States can examine and consider as it develops its own reforms to improve equity, taking into account the specific context and challenges of its own system. As students in the United States are diverse, local states and districts can assess student needs to discover which particular equity policies might best respond to those needs. Improving equity is not just about specific targeting of disadvantaged students; it is about creating a system of high-quality education across all schools. It is important not only to raise the performance of students who are falling behind, but also to ensure that all students can achieve their full potential, regardless of their socio-economic background.

Canada, Estonia, Germany and Hong Kong (China) show that high-equity systems are strategic and focused on high standards for all schools. These systems invest in ensuring that the teaching profession is attractive and that teachers have the skills and resources to give excellent instruction. Disadvantaged students in these systems are less likely to fall behind, because they are supported by early childhood education and other in-school and out-of-school resources that may typically only be available to advantaged families in the United States. Finally, these systems have a well-established strategy for reform that focuses on a continuous cycle of improvement. These are the types of policies that the United States could explore so that it can help all its students gain the skills and knowledge for success in education and careers.

Notes

1. Unless stated otherwise, references to figures and tables starting with "I" or "B2.I" refer to *PISA 2015 Results (Volume I): Excellence and Equity in Education* (OECD, 2016a).

2. Unless stated otherwise, references to figures and tables starting with "II" refer to *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools* (OECD, 2016c).

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4

Approaches to science education for 21st century learning in the United States

This chapter explores approaches to science instruction and presents examples of science teaching and learning focusing on students' application of knowledge. It also describes dimensions of curriculum, pedagogies and classroom instruction to effectively implement such standards. The ideas on instructional practices will feed into the debate in the United States, as the country reflects on the results of PISA and further discusses how to help students develop science literacy.

What is expertise? At one time, someone who simply retained a lot of scientific facts and data might have been considered an expert. But cognitive studies of expertise, starting in the 1980s, and more recent analyses of the interpersonal and social nature of learning and competence suggest there is more to this (Bransford, Brown and Cocking, 2000; Chi, Glaser and Farr, 1988; Sawyer, 2006). Expertise lies not just in the number of facts people have at their fingertips, but in how they can organise that knowledge and apply it flexibly and appropriately in new situations.

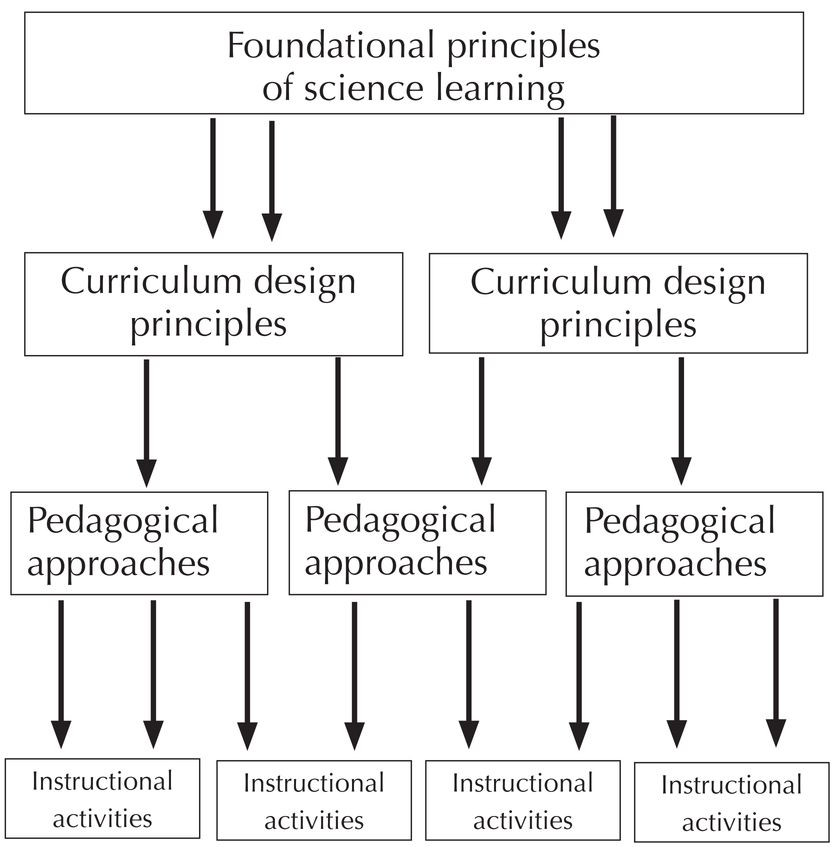
People need to understand the implications of the application of scientific knowledge and the issues it might pose for themselves or society. Scientific literacy requires not just knowledge of the concepts and theories of science, but also knowledge of the common procedures and practices associated with scientific enquiry and how they enable science to advance (OECD, 2016a). Furthermore, the long-admired virtues of critical thinking and problem solving are no longer viewed as generalised capacities for abstract thinking, but rather as forms of thinking within specific domains that work in combination with content knowledge.

These conceptions of expertise or literacy frequently appear as objectives of K-12 (primary and secondary education, including kindergarten) science instruction in the United States and for science instruction and assessments internationally, including on the OECD Programme for International Student Assessment (PISA). This chapter presents examples of standards of science instruction focusing on students' application of knowledge and describes dimensions of curriculum, pedagogies and classroom instruction to effectively implement such standards. The chapter further explores some examples of teaching methods to enhance students' application of knowledge, introducing elements to feed into the discussion of how instruction systems can help students develop such skills.

Science learning for 21st century must be designed across interdependent levels of the educational system, from frameworks for fundamental principles of science learning to curriculum design, pedagogical approaches and instructional activities in classrooms (Figure 4.1).

■ Figure 4.1 ■

Pathways to constructing a vision of science instruction



Foundational principles of science inform curriculum design principles and curriculum designs, integrating multiple principles of science learning. Curriculum designs are aligned with specific pedagogical approaches. These three levels then lead to specific implementation of day-to-day instructional activities by teachers. These levels are all inter-related and have feedback mechanisms to improve and refine each level. For example, research on implementation of instructional activities can provide insights on how well different pedagogical approaches work within certain curricula. This chapter examines reform and policy efforts, as well as the best practices that inform those efforts, at every level of the education system.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, developed by the National Research Council in 2012 (National Research Council, 2012), is one example of definitions of science literacy in standards documents. The Framework and its successor, The Next Generation Science Standards (NGGS) (NGSS Lead States, 2013), are examples of standards that emphasise learners' abilities to use and apply knowledge in accordance with the norms and practices of science disciplines. Some 20 states have currently adopted the NGSS.

In contrast to the earlier National Science Education Standards (National Research Council, 1996), that treated science inquiry processes and core concepts in the various domains as separate learning goals, the Framework states that science practices and science content must be integrated in order to practise and understand science. The Framework describes competencies in science as: 1) the integration of **concepts** (such as causality) that cut across many fields of science; 2) the **practices** that scientists and engineers use (such as evidence-based argument); and 3) the **core ideas** in particular science disciplines (such as natural selection). Science competence lies in the ability to orchestrate all three dimensions. Science learning is a trajectory in which these inter-related dimensions of competence emerge over time, with expected progressions of increasingly sophisticated understandings, not just within an instructional unit, but over years (National Research Council, 2012).

Similarly, international assessments such as PISA and the Trends in International Mathematics and Science Study (TIMSS), as well as several US state assessment efforts, include measures of things like collaborative problem solving and design as part of engineering literacy. The set of objectives and frameworks on which such assessment objectives are articulated reflect a knowledge-in-use conception of scientific literacy. The influence of this conception of science literacy on curriculum design, pedagogical approaches and instructional design is visible in efforts to evaluate or describe science instruction materials (Box 4.1).

Box 4.1 **Systematising the goals and features of science instruction materials**

The Global STEM Alliance (GSA), established by the New York Academy of Sciences, seeks to identify relevant science instruction materials and resources for practitioners. Working with SRI International, a non-profit research institute, the GSA developed a rubric to systematise the description of goals and features of science instruction materials. Dimensions of the GSA rubric reflect recent definitions of scientific literacy, with a focus on higher-order reasoning and 21st century skills as manifest in principles of overall curriculum design, the pedagogical approaches integrated and the design of specific instructional activities.

Source: Global STEM Alliance, http://globalstemalliance.org/.

CONSIDERATIONS FOR DEVELOPING SCIENCE INSTRUCTION IN THE UNITED STATES

Daily classroom instruction is the result of interdependent, system-wide processes to implement the curriculum. Instruction is linked to policy through standards and accountability efforts, curriculum, pedagogical resources and the pedagogical expertise of individual teachers. Each of these processes or collections of resources embodies a set of conjectures about the goals and forms of science instruction that shapes the possibilities of classroom activity.

From a classroom-instruction point of view, the ideas and principles put forth in policy frameworks can inspire and provide guidance for teachers' daily instructional decisions. Aligned curriculum resources can help put those daily decisions into practice by providing a roadmap through instructional content, with guidance about appropriate activities, cross-cutting concepts to help students make sense of big ideas, and known learning challenges. Similarly, knowledge of pedagogical approaches that support the implementation of instructional goals, combined with expertise in applying them, is another critical resource for creating the science classroom envisioned by current educational research and policy. If these resources are not coherently organised around a common view of learning and instruction, teachers will struggle to implement the goals within them (Cheng et al., 2015). Moreover, if local policy initiatives are not aligned with the goals of broader policy instruments or the principles underlying the curriculum, conflicting goals can swamp any potential benefit of individual resources.

The next section describes principles at each of these levels that have an influence on classroom instruction.

FOUNDATIONAL PRINCIPLES OF SCIENCE LEARNING

Foundational principles of science learning, presented in standards documents, accountability frameworks and other policy instruments, influence the kinds of curricular materials selected by administrators or teachers and the ways in which teachers use those materials with their students. Three foundational principles underlie the directions of the Framework for K-12 Science Education: 1) active and generative science instruction; 2) science instruction building on students' knowledge, interests and backgrounds; and 3) science instruction taking into account and reflecting our knowledge of the nature of science.

The principles presented here are not a complete survey of the foundational principles of science learning. Based on the Framework and the Next Generation Science Standards, they depict instruction that could engage students in using scientific knowledge and practices as part of empirical investigation and problem solving. These competencies reflect the *PISA 2015 Assessment and Analytical Framework*, which outlines three competencies as part of the importance of scientific literacy for students: 1) the ability to explain scientific phenomena; 2) the ability to evaluate and design scientific inquiry studies; and 3) the ability to interpret the scientific data captured in the inquiry (OECD, 2016a).

Active and generative science instruction

Through active and generative science instruction, students take an active part in planning and conducting their own investigations and, thus, their own learning. This can take many forms, including hands-on inquiry activities, in-depth classroom discussions among students and independent research on a topic. In some cases, students are given the assignment of helping to determine the shape and direction of portions of their lessons, thereby taking an active part in their own learning and the trajectory of that learning.

"Active instruction" can have multiple meanings. It can mean *active* in the sense of physically moving around the classroom, participating in group discussions and doing hands-on activities. It can also mean *active* in the sense of actively considering new ideas, trying to reconcile them with current ideas and sharing those ideas with others.

Instructional activities that support students to generate their own evidence or information can convey important values about the processes of scientific investigation and encourage students to participate in science instruction and, ultimately, in science careers (Vosniadou et al., 2001). Well-designed activities allow students to evaluate how their results comport with accepted scientific ideas. This can be a subtle shift from prior instruction that might have focused on doing laboratory activities that merely verified previously known information. While generative instruction can present students with familiar activities, their purpose and framing is centred around the idea that students generate their own conception of the problem at hand.

Science instruction building on students' knowledge, interests and backgrounds

Students construct meaning from new experiences, based on their prior knowledge, ideas and beliefs, and in response to the context of a learning activity. In contrast to the notion that students simply accumulate new knowledge, instruction can focus on integrating new ideas into students' currently held conceptions (Linn, 2006; Linn and Eylon, 2011).

Instruction can explicitly recognise the strong influence of prior knowledge in the learning process to address commonly held ideas that are non-normative. For example, students' beliefs or ideas can influence how they interpret observations. If students believe that a heavier ball will fall to the ground faster than a lighter ball, they will sometimes report hearing the heavier ball hit the ground first, even if the two balls hit at the same time. Constructivist instruction could help ease these challenges by paying particular attention to the ideas and knowledge that students bring into the classroom, and creating opportunities for students themselves to evaluate those ideas (Abbott and Fouts, 2003).

Instruction that builds on students' interests provides an engaging context for student work in the classroom. It also explicitly links schoolwork to topics that students may encounter outside of school, topics that they seek out on their own that may seed a life-long interest, hobby or career. Similarly, relating science instruction to students' backgrounds can help them to connect ideas and practices in the classroom to their activities outside of school. This can make science more relevant to their lives and broaden the types of endeavors students feel are possible and valuable for them, both in and out of school.

Culturally-relevant pedagogy

Another benefit of connecting instruction to students' knowledge, interests and backgrounds is explicitly valuing the cultural resources students bring to school. Modelling the integration and appreciation of the diversity of student backgrounds in science classrooms reflects a culturally diverse and culturally sensitive workforce in which students will take part. More importantly, it recognises students' identities and encourages their participation, without imposing a set of norms or values implicit in the classroom (Ladson-Billings, 1995a and 1995b).

Science instruction reflecting the nature of science

The nature of science refers to the epistemological underpinnings of the scientific enterprise and all of the knowledge that results from it. Six general aspects of science fall under this heading (Lederman, 2007): 1) understanding the difference between observations and inferences; 2) understanding the distinction between scientific laws and theories; 3) science involves human imagination and creativity; 4) scientific knowledge is subjective and/or theory-laden; 5) science is a human enterprise practiced within the context of larger cultures; and 6) scientific knowledge is never absolute or certain. Two other aspects of the nature of science are particularly relevant: 1) science is an empirical practice; and 2) science is a social practice.

Science is an empirical practice

The empirical nature of science is perhaps most important, as it differentiates science from other ways of knowing about the world. Science is a process that systematically collects information about the world, to answer well-designed questions based on prior understandings. The types of questions that science can answer are therefore limited by those that are focused on the observable world. The PISA 2015 Framework includes the construct of the epistemic knowledge of science, asking students to understand the goals and purpose of science, the nature of different types of reasoning in science (deductive, inductive, abductive, analogical and model-based) and the difference between observations, facts, hypotheses, models and theories. For example, an important outcome for science instruction is understanding the difference between observations and theories, and the role that each plays in the larger practice of science and its empirical nature.

Science is a social practice

One aspect of science that gets less attention, especially from the general public, is the notion that scientific knowledge and scientists exist within a larger culture that cannot be separated from the knowledge that is produced. Science is a human enterprise and is, therefore, influenced (sometimes in subtle ways) by the biases, cultural norms and customs of the cultures in which it exists. There are two main consequences of this. One is that scientific knowledge must be understood with these inherent biases. The current explanations of the world around us are coloured by the norms and biases of the humans involved in creating them. It is important for students to remember this when interpreting scientific results, especially those that are associated with a different time period or location. The other consequence for instruction revolves around the idea that science is created. The construction of knowledge that students experience in classrooms is, in many ways, a microcosm of the larger scientific community. This can help give importance and legitimacy to students' construction of ideas, because they can see that the general process they go through mirrors that of professional scientists. Students can create scientific knowledge that is personal and connected to their local community by answering questions about the world around them in a systematic way.

SCIENCE CURRICULUM DESIGN

Curricula play a vital role in the construction of instructional objectives, practices, activities, and teaching and learning materials. They support the practical work of translating foundational principles into discipline-specific organisation of knowledge and practice. They map a vision of learning on to subject areas, identifying and linking what should be learned in a sequence that can be implemented in educational institutions, with their existing classrooms, science labs, equipment and materials. This section describes the principles of curriculum design and the elements that must be taken into consideration. It also highlights examples of approaches to support students' learning presented in the Framework for K-12 Science Education and the Next Generation Science Standards.

Learning progressions

The Framework and the NGSS place core scientific ideas in standards that cross grade levels. The Framework describes learning a specific idea as a developmental process, extending over time rather than acquired all at once. It also proposes instruction that supports longer-term revisiting of core ideas, integrating more detailed and sophisticated explanations of phenomena each time as an integral component of the organisation and sequence of the standards.

STEM mindsets

Scientists rarely find an answer to a scientific inquiry on their first attempt. Grit and persistence are important mindset approaches that scientists practise as part of their daily work. Researchers posit the importance of underscoring this point to students who are learning science, as this non-cognitive skill is critical for success in long-term goals (Duckworth et al., 2007; Subotnik, Olszewski-Kubilius and Worrell, 2015). Persistence means continued effort at a task and adopting novel approaches as necessary when encountering obstacles during a problem-solving activity. Academic fields like engineering, science and mathematics often require both long-term projects and challenging courses. Research shows that when students demonstrate perseverance and success in early foundational courses, they are more likely to experience success in advanced courses in these subjects (Subotnik, Olszewski-Kubilius and Worrell, 2015). Moreover, studies focusing on groups that are typically under-represented in math and science fields also show that academic persistence plays an important role in these students' success and their continued participation in science, technology, engineering and mathematics (STEM) courses (Mau, 2003; Russell and Atwater, 2005).

Diversity and accessibility

Learners' individual identities and their cultural and social experiences and beliefs offer a critical lens through which students identify as science learners and experience their learning (Nasir, 2007; Nasir and Hand, 2008; Preece, 2009). This principle of culturally sensitive learning becomes a more pronounced concern when students do not see other people like themselves as being successful in scientific practice and scientific professions. This is particularly true in the United States, where gender and minority groups are grossly under-represented in STEM fields. For example, research on the learning experiences of African-American students underscores the need to offer more direct programming to schools serving these students, in order to enhance their learning experience (Ladson-Billings, 1995a; Tate, 1995).

The needs of students with disabilities have traditionally been ignored in instructional design. Universal Design for Learning (Rose and Meyer, 2002) is a framework that guides designers to develop materials that are accessible to students with a range of physical, auditory, visual, cognitive and other disabilities.

Ethics and societal implications

Science often deals with socially sensitive subjects that have ethical implications for national and international policies and human progress (such as genetic engineering, human cloning, testing on humans by pharmaceutical firms or intelligence agencies, economic and political ramifications of evidence on global climate change) (Resnik, 2005). Scientific work involves a wide range of ethical concerns for scientists and engineers. These include fabrication of data, restricting criticism of scientific work, plagiarism, failing to give credit, lack of respect for subjects of scientific research, abdicating social responsibility to inform the public, and failing to obey the law. It is crucial to discuss these important issues with students and to educate them in ethical scientific practices, both informally (modelling by teachers and mentors) and formally (direct instruction) (Hollander et al., 1995).

PEDAGOGICAL APPROACHES TO SCIENCE INSTRUCTION

In school districts, schools and individual classrooms, administrators and teachers draw on their expertise in pedagogical processes to complement the learning objectives embedded in curricula and policy frameworks. These pedagogical approaches are deeply connected to curriculum design and to specific forms of instructional activity, but they also function independently.

Project-based learning

Project-based learning or problem-based learning (PBL) focuses on students "doing [science] with understanding". It engages students in focused problem solving in order to stimulate deep reflective understanding of the process and purpose of problem solving, rather than just following specific pre-decided steps (Barron et al., 1998; Barrows, 1996; Savery, 2006; Strobel and Van Barneveld, 2009). PBL is closely aligned with a knowledge-in-action perspective of students building and using their science knowledge within the context of solving problems. PBL also has a strong collaborative or social component, since students work together toward common learning goals, allowing for creative, diverse perspectives and reflective thinking (Blumenfeld et al., 1996).

Cross-disciplinary integration

An emerging approach in schools across the United States is to integrate science content into the humanities, social science, art and other subject areas. This allows science learning to be contextualised and is seen as a valuable approach (Honey, Pearson and Schweingruber, 2014). In the United States, this perspective is reflected in both the Common Core State Standards for Mathematics (NGA Center and CCSSO, 2010) and the Next Generation Science Standards (NGSS Lead States, 2013), which both call for more and deeper connections among school subjects.

Real-world applications and contexts

Students engage more in science learning when what they are learning and doing in science classrooms has relevance to their everyday lives outside of school. A growing number of science classrooms and after-school programmes in the United States are asking students to apply science knowledge to real-world issues and problems as part of the curriculum (Darling-Hammond, Ancess and Falk, 1995; Hoachlander and Yanofsky, 2011; Kolodner et al., 2003). For example, in US high schools, engineering pathway classes require students who are learning algebra and geometry to design architecture that can withstand earthquakes, or to use computer programmes to apply mathematics to develop virtual models of that architecture (Hoachlander and Yanofsky, 2011). Such examples of contextualised learning demonstrate how students are developing and applying problem-solving skills and reflective inquiry, reinforcing their science-content learning and getting better prepared to apply their knowledge of mathematics and science in higher education and careers in STEM (Hiebert et al., 1996; Hoachlander and Yanofsky, 2011; Kolodner et al., 2003).

Formative assessment aligned to instruction

Formative assessments are typically given at the beginning of a lesson so that instructors can identify students' current knowledge and the topics they may be struggling with (Black and Wiliam, 1998 and 2009). These assessments serve as critical tools for instructors to ensure that student learning is progressing on track. Summative assessments provide a more comprehensive view of student learning at certain intervals, generally following an extended period of instruction or intervention.

The main purpose of formative assessment is the feedback it provides to both learners and instructors about gaps in students' learning, so that further instruction and support may be provided to bridge those gaps. It is critical that assessments be aligned to instruction to make them informative to both teachers and students. Teachers who regularly implement formative assessments – both formalised assessment tasks and less formal check-ins – are in a better position to adjust instruction to address student challenges and provide opportunities for deeper learning when appropriate. Students who regularly receive feedback can begin to gauge their own progress and recognise the need for additional help from teachers and peers.

Box 4.2 **Teaching strategies and students' performance in PISA**

PISA 2015 asked students who attend at least one science course how often certain activities happen in their science lessons. The teaching strategies used by teachers are grouped into four approaches: teacher-directed instruction, perceived feedback, adaptive instruction and enquiry-based instruction. According to students' reports, these teaching approaches are not mutually exclusive, even if some teaching approaches, such as adaptive teaching and providing feedback, are more frequently combined than others.

When students in OECD countries were asked about what happens in all or most lessons, almost seven in ten reported that they are given opportunities to explain their ideas, about six in ten reported that their science teachers explain how a science idea can be applied to different phenomena, and half reported that their teachers explain the relevance of science concepts to their lives. Only one in four students or fewer reported that they are allowed to design their own experiments, spend time in the laboratory doing practical experiments, or are asked by their science teacher to do an investigation to test their ideas.

In all OECD countries except Korea, using teacher-directed instruction more frequently is associated with higher science achievement, after accounting for the socio-economic status of students and schools; and students in all countries also hold stronger epistemic beliefs, such as believing that scientific ideas change in light of new evidence, when their teachers used these strategies more frequently. A positive association is also observed between these teaching practices and students' expectations of pursuing science-related careers. In no education system are these instructional practices associated with students being less likely to expect to work in science-related occupations.

In 27 of the countries and economies that participated in PISA, students in socio-economically disadvantaged schools are more frequently exposed to enquiry-based teaching than those in advantaged schools, while the reverse is true in 10 other education systems. After accounting for the socio-economic profile of both students and schools, greater exposure to enquiry-based instruction is negatively associated with science performance in 56 countries and economies. Perhaps surprisingly, in no education system do students who reported that they are frequently exposed to enquiry-based instruction score higher in science. However, across OECD countries, more frequent enquiry-based teaching is positively related to students holding stronger epistemic beliefs and being more likely to expect to work in a science-related occupation when they are 30, even if these relationships are weaker than is the case with teacher-directed and adaptive instruction.

...

These results require cautious interpretation. Compared with teachers of other school subjects, such as literature, mathematics or geography, science teachers often use expensive and sophisticated equipment in their lessons, particularly if students are expected to participate in laboratory work. At the same time, teachers often mention a lack or inadequacy of resources, in addition to large classes, a lack of time and safety issues, as barriers to incorporating enquiry-based learning in their lessons (Cheung, 2007; Hofstein and Lunetta, 2004; Lawson, Costenson and Cisneros, 1986). If students are given sufficient time for reflection and connect their experiments with what they have learned earlier, and if teachers find meaningful ways of assessing their students' laboratory work, conducting experiments can motivate students and improve their understanding of the nature of science (Gunstone and Champagne, 1990; Hofstein and Lunetta, 2004; Tobin, 1990; Yung, 2001). Virtual experiments are often mentioned as a cheaper and safer alternative to physical manipulation; but even if some studies have shown that the two are equally effective in promoting conceptual understanding of science (Zacharias and Olympiou, 2011), real experiments may instil greater motivation in students (Corter et al., 2011).

Source : OECD (2016b), *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools*, PISA, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264267510-en.

SCIENCE INSTRUCTION ACTIVITIES

Each of the foundational principles of learning, curriculum design principles and pedagogical approaches discussed in this chapter can be implemented in familiar instructional activities or as part of novel forms of instruction. The following section highlights instructional designs that engage students in classroom activities that elicit 21st century skills and deeper reasoning about core science ideas and science and engineering practices. These activities comprise day-to-day steps to achieve the new vision of science literacy and instruction and must be carefully implemented in order to maximise their effects (see Box 4.3).

Collaboration

Collaboration is a critical requirement for scientific inquiry. Scientists in all disciplines exchange ideas and work collaboratively. This inherent nature of science underscores the need to engage students in scientific discourse, argumentation, exchange of ideas and collective building of scientific knowledge (Driver, Newton and Osborne, 2000; Duschl and Osborne, 2002; Minner, Levy and Century, 2010). Student collaboration can be encouraged by way of small-group work, starting with defining a common goal for group members, assigning each individual a role in the scientific inquiry, creating accountability systems, and finally reflecting on the quality of work as a group (Springer, Stanne and Donovan, 1999). Even for students who may not be in the same physical location, collaboration tools are available for online learning environments (Brindley, Blaschke and Walti, 2009; Curtis and Lawson, 2001; Edelson, Gordin and Pea, 1999).

Technology-rich instruction

In today's digital age, people are increasingly dependent on technology, and students being trained in scientific thinking and practice can clearly benefit from the use digital tools as part of the curriculum. Technology is used in various ways (Dede, 2000):

- to gather information and demonstrate comprehension (understanding information, comparing and contrasting, and summarising)
- to analyse (recognising patterns, and organising and ordering information)
- to apply knowledge (generalising information to new situations and solving problems)
- to synthesise and evaluate (evaluating evidence and concluding).

Twenty-first century skills include the use of advanced computing and telecommunications to solve real-world problems. For example, technology can be a tool for collaboration among students (Bingimlas, 2009; Osborne and Hennessy, 2003). Technology-rich instruction also includes computational thinking, another important 21st century skill. Computational thinking focuses on students' understanding and use of computers to help solve data-related problems, including through symbolic representation, iteration and logical operators, and algorithmic thinking.

Box 4.3 **More technology, better performance?**

The relationship between introducing more technology in classroom and better student performance seems to be far from direct, with many actors involved in making the required changes happen. Evidence from PISA 2012 shows only a weak or sometimes negative association between the use of information and communication technology (ICT) in education and performance in mathematics and reading, even after accounting for differences in national income and in the socio-economic status of students and schools. It is important to ensure that schools and education systems are ready to leverage the potential of technology. The following challenges need to be addressed as part of the technology plans of schools and education ministries: gaps in the digital skills of both teachers and students, difficulties in locating high-quality digital learning resources from among a plethora of poor-quality ones, a lack of clarity on the learning goals, and insufficient pedagogical preparation for blending technology meaningfully into lessons and curricula.

Source: OECD (2015), *Students, Computers and Learning: Making the Connection*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264239555-en.

Opportunities for communicating about science

Twenty-first century skills have underscored the vital importance of communication skills (Duffy et al., 2004), including the ability to use new modes of technology. Science requires professionals to not only demonstrate their ability to listen well to others, but also to skillfully communicate their own scientific understanding and share scientific explanations and ideas through various visual mediums (Bell, 2010; Dede, 2010; Trilling and Fadel, 2009). Students should be able to effectively communicate assumptions and ideas, evidence and counter-evidence, as well as be able to present effective and reasoned arguments (P21, 2009).

Working with data

Data play a key role in scientific investigations in our daily life. Whether the data are qualitative or quantitative in nature, students must be able to appropriately choose which data to gather, identify the right tools to gather the data, analyse the data, and then use the data to answer a question or build a model. As students gain expertise in working with data, relevant skills can be expanded to judging the quality of data and different ways of visualising and presenting data effectively. For quantitative data, there are opportunities to integrate many mathematical concepts into science instruction. For qualitative data, there are opportunities to discuss the wide range of types of scientific investigations that produce this kind of data, and different ways of analysing and interpreting the data. Activities can incorporate three different kinds of data:

- given data that students must analyse (a more traditional approach to working with data that tries to minimise messy data)
- data that students collect themselves (during an investigation that they may or may not have planned)
- real-world data sets that are typically used by professional scientists (which can be difficult to find or use but can be more engaging for students).

In addition, data literacy, or the ability to work with scientific data, is an important 21st century skill for future scientists and a scientifically-informed citizenry. These skills include interpreting data, being able to judge when inadequate data are provided and knowing how to analyse data to generate knowledge (Ryder, 2001).

Scientific modelling

The use, development, and evaluation of scientific models are important practices for scientists as well as for students who are learning about science. Models are ubiquitous in science, used to help illustrate or describe scientific phenomena by simplifying and clarifying the important features. Scientific models can be used to generate explanations and predictions about phenomena. They can be mathematical representations, diagrams, physical objects, analogies or even computer simulations. When used in science instruction, models are seen to have certain components:

- the elements or features of the model that represent the phenomena
- the relationships between those elements
- the correspondence of the representation of the elements to their real-world counterparts
- the limitations of the model.

Guiding students through these components of models and the ways in which models are used to explain and make predictions about phenomena could help students better understand the process of science and how scientists make sense of the world.

Scientific investigation

Scientific investigation is a core practice of science, the main method for gathering information that can be used to understand the world around us. A scientific investigation is a systematic procedure that is developed and carried out in order to answer a specific scientific question. The practice involves three elements:

- planning the investigation (deciding on important variables, methods for collecting data, the amount of data needed, appropriate tools and possible sources of error)
- carrying out the investigation (setting up and using tools appropriately, making the planned measurements and generally following the plan)
- evaluating the investigation (examining how well the plan was followed).

Explanation and argumentation

Explanation and argumentation are two related practices that address key aspects of the scientific approach and how to communicate ideas to others. Explanations are statements that answer a question about how or why a phenomenon is occurring, as well as the evidence and scientific reasoning to support that claim. The claim-evidence-reasoning framework (McNeill and Krajcik, 2011) is a common way to engage students in the practice of explanation during instruction. Argumentation is a more formalised way of coming to consensus with others about scientific ideas. Through argumentation, students present their claim and the evidence, scientific principles and warrants (why those scientific principles are appropriate to use to connect that evidence to support that particular claim). While argumentation and explanation can seem similar in structure, their aims are slightly different. Explanation aims to create an evidence-backed answer to a scientific question, while argumentation aims to convince others that your answer is more correct. Argumentation can be viewed as more of a process, while explanations are products that can be created through that process.

CONCLUSION

From broad goals to frameworks, guidelines, best practices, assessments and resources, science education in the United States has been in transformation for the last three decades (Bybee and McInerney, 1995). That transformation requires millions of educators in thousands of independent school districts to change their instructional practices and curricula to improve students' learning.

In the United States' decentralised education system, states, districts and schools can, to varying degrees, introduce and implement their own standards. Currently, 20 states have adopted the Next Generation Science Standards. An additional 25 states have adopted the Framework for K-12 Science Education (National Research Council, 2012). Adoption of the standards is a broad indicator of the vision of teaching and learning defined at the top level of an education system, but that vision needs to be fully implemented to reach the classroom and impact on learning.

To translate principles and standards into curriculum, pedagogies and teaching in order to achieve quality learning for all, systems should be developed to support their implementation. In the context of the decentralised US education system, it is important for states to ensure that critical infrastructure is well designed and put in place – including funding and support for teachers and school leaders. Although the underlying principles of the new vision of the Next Generation Science Standards promote equity and access to deeper learning for all students, variation among state expenditures continues to challenge educational equity (Tienda, 2016).

This chapter has explored approaches with significant potential to enhance students' skills to apply knowledge. It is also important to further examine and consider curricular and pedagogical approaches for developing knowledge and the interaction between learning knowledge and applying it, in a whole design of learning.

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