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What PISA 2015 results imply for policy

A solid base of science literacy is necessary not just for those who are interested in becoming scientists and engineers; all young people need to understand the nature of science and the origin of scientific knowledge so that they can become better citizens and discerning consumers. This chapter analyses what the disparities in student performance, attitudes towards science and expectations of pursuing science-related careers imply for education policy and practice.

A note regarding Israel

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.



From taking a painkiller to determining what is a “balanced” meal, from drinking pasteurised milk to deciding whether or not to buy a hybrid car, science is pervasive in our lives. Science is not just test tubes and the periodic table; it is the basis of nearly every tool we use – from a simple can opener to the most advanced space explorer. Nor is science the domain of scientists only. Everyone now needs to be able to “think like a scientist”: to be able to weigh evidence and come to a conclusion; to understand that scientific “truth” may change over time, as new discoveries are made, and as humans develop a greater understanding of natural forces and of technology’s capacities and limitations.

The PISA 2015 assessment focused on 15-year-olds’ science literacy – their knowledge of natural and technological phenomena and their ability to think like scientists – while also assessing their proficiency in reading and mathematics. As the world has changed in the 15 years since the first PISA test was conducted, the test, itself, has evolved too to reflect those changes. For the first time, in 2015 the test was delivered entirely on computer in order to allow for more dynamic and interactive assessment tasks. This change should be seen as an acknowledgement that not only are most of today’s 15-year-olds already fluent in computer use, but that no matter what occupation they may ultimately choose for themselves, that kind of fluency will be required if these students are to participate fully in their societies.

The last time PISA focused on science was in 2006. Since then, the world of science and technology has changed significantly. The smartphone (e.g. Android, the iPhone and the iPad) was invented and became ubiquitous. Social media (e.g. Facebook, Twitter, YouTube), cloud-based services and advances in robotics/machine learning, based on Big Data, became available and have had a profound impact on our economic and social life (e.g. speech recognition, translation, financial trading, autonomous vehicles, and logistics). The Internet of things as well as augmented and virtual reality emerged. Also, biotechnology advanced considerably since 2006, as evidenced in the possibilities of gene sequencing and genome editing, synthetic biology, stem-cell therapies, bio-printing, optogenetics, regenerative medicine and brain interfaces that became available since then. Against this backdrop of rapid scientific and technological change, it is disappointing that for the majority of countries with comparable data, science performance in PISA remained virtually unchanged since 2006. In fact, only a dozen of countries showed measurable improvement in the science performance of their 15-year-olds, including high-performing education systems, such as Singapore and Macao (China), as well as low-performing ones, such as Peru and Colombia.

HOW UNIVERSAL ARE BASIC SKILLS?

In September 2015, the world’s leaders gathered in New York to set ambitious goals for the future of the global community. Goal 4 of the Sustainable Development Goals (SDG) seeks to ensure “inclusive and equitable quality education and promote lifelong learning opportunities for all”. This includes that “all learners acquire the knowledge and skills needed to promote sustainable development” (Target 4.7). One way to assess and monitor how well countries are preparing their students for life after compulsory education is to determine the proportion of 15-year-olds who score above the baseline level of proficiency in the PISA test.

In all three PISA core subjects, the baseline level is the level at which students are able to tackle tasks that require, at least, a minimal ability and disposition to think autonomously.

In science, the baseline level of proficiency corresponds to the level at which students can not only use everyday knowledge about familiar scientific phenomena to recognise the correct explanation for them, but can also use such knowledge to identify the question being addressed in a simple experimental design or to identify, in simple cases, whether a conclusion is valid based on the data provided.

In mathematics, the baseline level of skills is defined as the level at which students can not only carry out a routine procedure, such as an arithmetic operation, in situations where all the instructions are given to them, but can also interpret and recognise how a (simple) situation (e.g. comparing the total distance across two alternative routes, or converting prices into a different currency) can be represented mathematically.

In reading, the baseline level of skills is defined as the level at which students can not only read simple and familiar texts and understand them literally, but can also demonstrate, even in the absence of explicit directions, some ability to connect several pieces of information, draw inferences that go beyond the explicitly stated information, and connect a text to their personal experience and knowledge.

The 2009 Canadian Youth in Transition Survey, which followed-up on students who were assessed by PISA in 2000, shows that 15-year-olds scoring below Level 2 in reading face a disproportionately higher risk of not participating in post-secondary education and of poor labour-market outcomes at age 19, and even more so at age 21 (OECD 2010).



A similar longitudinal survey in Switzerland, which followed the PISA 2000 cohort until 2010, shows that students scoring below Level 2 in reading are at high risk of not completing upper secondary education. About 19% of students who had scored at Level 1, and more than 30% of students who had scored below Level 1 had not completed any upper secondary programme by the age of 25, compared to less than 10% of those students who had scored above the baseline level of proficiency in reading (Scharenberg et al., 2014).

Two follow-up studies in Uruguay, based on the 2003 and 2006 PISA cohorts, similarly indicate that students who had scored below Level 2 in the mathematics tests were significantly less likely to complete upper secondary education (Cardozo, 2009) and more likely to have repeated a grade or dropped out of school, even after accounting for other demographic and social differences among students (Ríos González, 2014). A Danish study that linked PISA to the Survey of Adult Skills (a product of the OECD Programme for the International Assessment of Adult Competencies, or PIAAC) also shows that students who had scored below Level 2 in reading in PISA 2000 were more likely to have received income transfers for more than a year between the ages of 18 and 27 – meaning that they were unemployed or ill for long periods (Rosdahl, 2014). And the Longitudinal Study of Australian Youth (LSAY) shows that the 25% of students with the lowest scores in mathematics in 2003 were more likely to be unemployed or not in the labour force in 2013 than the second 25% of students (LSAY, 2014).

The share of students who achieve the baseline level of skills in all three domains (science, reading and mathematics) varies considerably across countries – from more than 80% in Canada, Estonia, Finland, Hong Kong (China), Japan, Macao (China) and Singapore, to less than 20% of students in some middle-income countries. The culturally and geographically diverse set of countries in the former group shows that on all continents, universal basic skills could become a reality within the next generation. At the same time, the small set of countries that achieves this benchmark today shows that much remains to be done in most countries – including some of the wealthiest OECD countries – to attain the Sustainable Development Goals (Table I.2.10a).

HIGHER PUBLIC EXPENDITURE ON EDUCATION HAS NOT ALWAYS DELIVERED BETTER RESULTS

Money is necessary to secure high and equitable performance in school, but it is not sufficient. Only one of the ten PISA-participating countries with the highest cumulative public expenditure per student up to age 15 – Singapore – is among the seven countries/economies where less than 20% of students are low achievers in any of the three domains. But these seven countries/economies include Estonia and Korea, whose public spending per student is below the OECD average.

Perhaps more important, several countries have increased expenditures over the past decade without seeing corresponding improvements in the quality of the learning outcomes measured by PISA. Across OECD countries, expenditure per primary and secondary student rose by almost 20% between 2005 and 2013 (OECD, 2016). Yet, on average across OECD countries, students' mean reading proficiency has stagnated since 2000 (Table I.4.4a), and there has been no notable reduction in the percentage of students performing below the baseline level of proficiency (Tables I.2.2a, I.4.2a and I.5.2a).

Financial resources can explain broad patterns of variation in performance in PISA. For example, 36% of the variation in mean scores is associated with differences in per capita GDP across countries; and 55% of the variation in mean scores is associated with differences in cumulative expenditure on students up to age 15. However, while money relates to learning outcomes among low-spending countries, for the majority of OECD countries there is essentially no relationship between spending per student and outcomes in PISA. What matters are how resources are allocated and the qualitative differences in education policies, cultural norms and professional practices that underlie the performance differences between and within countries (these are discussed in Volume II).

The countries that have improved the most in PISA over the past decade have often shown the capacity to find solutions to the challenges they face, using PISA and other robust sources of evidence, as both a mirror and a way to build consensus about the priorities for action. It is not unusual to see PISA-participating countries improve rapidly between the first two assessments in which they participate. Such improvement could indicate that countries are harvesting some of the early fruits of their efforts to improve their education systems. But sustained improvement over several years and PISA assessments is much more difficult to achieve. Colombia and Portugal are among the few education systems whose reforms have been successful in improving average student performance in science over successive PISA cycles.

ACCESS TO EDUCATION IS STILL NOT UNIVERSAL

In many countries, improving the quality of education will not be sufficient to ensure that, by 2030, all young people leave compulsory schooling with basic skills; these countries must also ensure that all young people complete primary and secondary education. In fact, in some countries, the 15-year-olds who are enrolled in school have access to excellent



education, but there are many 15-year-olds who are no longer in school to benefit from it or are held back in primary grades. In Beijing-Shanghai-Jiangsu-Guangdong (China) (hereafter “B-S-J-G [China]”) and Viet Nam, for instance, there are fewer low-achieving students in school than on average across OECD countries; but the PISA target population represents less than 50% of the overall population of 15-year-olds in Viet Nam, and only 64% in B-S-J-G (China).

Meanwhile, in Brazil, Costa Rica, Lebanon and Mexico, fewer than two in three 15-year-olds are in school and eligible to participate in PISA; but among these students, at best about one in three (36% of students in Mexico) attains the baseline level of performance in all three domains. These countries face a double challenge: they must expand secondary education while also ensuring that students who complete compulsory education are at least able to read and understand texts, and to use numbers, at a level that enables them to further develop their potential and participate in knowledge-based societies.

While some OECD countries, and more partner countries and economies, are further from securing universal enrolment for their 15-year-olds, many of them have been gradually advancing towards this goal over the past decades. For instance, between 2003 and 2015, the population of 15-year-olds enrolled in grade 7 or above increased by almost 500 000 students in Brazil, by more than 375 000 students in Turkey and by more than 300 000 students in Mexico, reflecting the increasing capacity of these countries to retain young people in school. These improvements are also evident in improved coverage rates of the national populations of 15-year-olds (enrolled and not enrolled) in PISA samples. Countries showing positive coverage trends also include Costa Rica, Indonesia and Uruguay.

Policies to increase participation in secondary education may focus on providing more resources to schools, either as a way of reducing direct costs of education for families or enabling schools to provide safer and more accessible environments, and specific learning support to children at risk of dropping out. An alternative policy approach is to allocate resources directly to students’ families, including through conditional transfer programmes that offer financial incentives to disadvantaged or marginalised families to encourage their children to enrol in and attend school. Brazil, Mexico and Peru have introduced such programmes. Mexico’s *Oportunidades* (now rebranded as *Prospera*) and *Programa de Becas de Media Superior* are examples of cash-transfers programmes to poor families aimed to raise enrolment rates in secondary education, especially among girls (OECD, 2013a).

Policy efforts to improve the inclusiveness of education systems through greater access to schooling are particularly urgent in countries with relatively low enrolment rates, and where demographic growth leads to larger populations of primary and secondary school-age children. Meanwhile, efforts to increase access to education should go hand-in-hand with the improvement of quality. Students and parents will not invest their time and resources in formal education if schooling does not improve students’ future outcomes.

COUNTRIES DO NOT HAVE TO CHOOSE BETWEEN NURTURING EXCELLENCE IN EDUCATION AND REDUCING UNDERPERFORMANCE.

Basic skills protect individuals from adverse consequences of rapid change in inter-dependent, knowledge-based economies; they help make future growth sustainable and societies resilient. But they are not sufficient for individuals and countries to thrive in a highly advanced economic and social environment. The solutions to the most complex problems that humanity faces today – from climate change to inter-cultural communication and managing technological risks – will come from creative individuals who are willing to engage with these difficult issues and have the ability to do so.

The proportion of top-performing students in PISA – students who are able to understand and communicate complex tasks, formulate mathematically situations that involve several variables, and use their knowledge of and about science to analyse unfamiliar or complex science-related issues – is an indicator of whether education systems succeed in nurturing excellence. On average across OECD countries, about one in six students performs at Level 5 or above in science, reading or mathematics (Table I.2.9a); among them, 3.7% of students are top performers in all three subjects. An estimated one million 15-year-olds in OECD countries can perform at this level in science (Table I.2.9c).

But top performers in PISA are not evenly distributed across countries. In 12 countries and economies – B-S-J-G (China), Canada, Estonia, Finland, Hong Kong (China), Japan, Korea, Macao (China), New Zealand, Singapore, Switzerland and Chinese Taipei – more than one in five students perform at the highest levels (Level 5 or 6) in at least one of the PISA domains; and in Singapore and B-S-J-G (China), 13.7% and 7.6% of students, respectively, reach this level in all three domains.

Macao (China) and Portugal were able to “move everyone up” in science, mathematics and reading performance over the past decade by increasing the number of top performers while simultaneously reducing the number of students who do not achieve the baseline level of skills. Their experiences demonstrate that education systems can nurture top performers and assist struggling students simultaneously.



At the same time, PISA also shows that some education systems prepare a relatively large number of students to achieve at the highest levels, but face bigger challenges in ensuring that struggling students do not fall too far behind. In mathematics, for instance, Switzerland has a significantly larger share of top-performing students than Estonia, despite similar average performance; Israel has a larger share of top-performing students than the United States. In reading, France has one of the largest shares of top-performing students (12.5%), but its mean performance is close to the OECD average. France, Israel and Switzerland do relatively well (compared with countries of similar average performance) in nurturing excellence, but at the same time, they have sizeable shares of students who do not reach the baseline level of proficiency.

GENDER DIFFERENCES IN PERFORMANCE PERSIST

Among the subjects of science, mathematics and reading, science is the one where mean gender differences in performance in PISA are smallest. However, overall similar average performance in science does not reflect the many girls who have difficulty achieving at the highest levels of proficiency – and the large number of boys who struggle to acquire basic skills. In all three domains, boys show larger variation in performance than girls, meaning that the best-performing boys are far ahead of the lowest-achieving boys. Among girls, the difference between the top and lowest performers is narrower.

But for each of these findings, there are considerable variations across countries and years. In Finland, for instance, there are more girls than boys among the top performers in science (and the share of top-performing girls in Finland exceeds the share of top-performing boys in most other countries that participated in PISA). In Hong Kong (China) and Singapore, two of the highest-performing countries and economies, similar shares of boys and girls perform at Level 5 or above in mathematics. In Colombia, the country with the largest gender gap in mathematics performance (in favour of boys) of all PISA-participating countries/economies in 2012, this gap narrowed significantly in 2015 – and the country's highest-achieving girls now score significantly closer to the country's highest-achieving boys. In the United Kingdom, the variation in performance is similar among girls and among boys in all three domains – science, reading and mathematics.

This indicates that gender disparities in performance do not stem from innate differences in aptitude, but rather from factors that parents, teachers, policy makers and opinion leaders can influence. A collective effort to encourage student attitudes that are conducive to success, among both boys and girls, and change the behaviours that impede learning can give boys and girls equal opportunities to realise their potential and to contribute to society with their unique, individual capacities.

Gender differences are also apparent in students' dispositions towards science-related careers, even among students who score similarly in science and who report similar levels of enjoyment in learning science. In Germany, Hungary and Sweden, for instance, boys who score at or above Level 5 in science (top-performing boys) are significantly more likely than top-performing girls to expect a career requiring further training in science (the opposite is observed in Denmark and Poland, but only because many more girls than boys in these countries expect to work as health professionals). This echoes findings from other studies in which many students report enjoying science, but do not perceive science as being something for them (Archer et al. 2010). Perhaps even when students hold positive views of scientists, in general, they find it hard to relate their image of a scientist to themselves (DeWitt and Archer 2015).

POLICY IMPLICATIONS OF RESULTS FROM THE PISA SCIENCE ASSESSMENT

Every day, the public is confronted with new messages based on science. “Revolutionary new toothpaste not only removes more plaque but could save you from a heart attack”; “A pill to cure autism? Study identifies defect in sufferers' cells – that could be treated by existing medication”; “A glass of red wine a day could keep polycystic ovaries at bay”. These are just a few of the headlines published on the website of a popular British tabloid on the morning of 19 October 2016.¹

When newspapers report about the side effects of common drugs; when a friend forwards the link to a website showing the “benefits” of drinking alcohol; when a toothpaste advertisement at the supermarket claims that it has been scientifically proven to kill “99% of bacteria” – it is up to the recipient of these messages to be able to separate science from spin, to identify misrepresentations of findings, and to assess the level of uncertainty, or the trustworthiness, associated with a particular claim. A solid base of science literacy is necessary not just for those who are interested in becoming scientists and engineers. Rather, all youth need to understand the nature of science and the origin of scientific knowledge so that they can become better citizens and discerning consumers.

For this reason, the PISA assessment of science measures not only students' knowledge of major facts, concepts and explanatory theories about the natural world and technological tools; it places equal weight on assessing students' knowledge and understanding of scientific methods and of the nature and origin of scientific knowledge. PISA assessment tasks (some examples of which are presented in Annex C and available on line at www.oecd.org/pisa) measure whether



students can explain phenomena scientifically; they also measure how able and willing students are to evaluate scientific enquiry and to interpret data and evidence scientifically. All three competencies are important in order to understand and engage critically with issues that involve science and technology – which are fast becoming ubiquitous.

PISA results also underline the importance of students' values, beliefs and attitudes towards science: support for scientific approaches to enquiry, interest in science and enjoyment of learning science are all positively related to performance in science and support further engagement with scientific issues over a lifetime. PISA data show, for instance, that students who do not agree that scientific knowledge is tentative are less likely to perform well in science than students who recognise that ideas in science are inherently provisional, and are sometimes revised based on new evidence. They also show that engagement with science and positive attitudes towards science are strongly related, in ways that also depend on students' proficiency in science. In particular, the positive relationship between performance in science and expectations of future careers in science is strongest among students who enjoy learning science the most. This may imply that widespread engagement with science does not come from high academic proficiency alone; nor can positive attitudes compensate for low proficiency. If educators focus on one to the exclusion of the other, then the influence of each is, most likely, undermined. Rather, these results indicate that positive attitudes and strong knowledge and competence reinforce each other in sustaining lifelong engagement with science.

Support widespread engagement with science while meeting the demand for scientific excellence

For most of the 20th century, school science curricula, especially in upper secondary education, tended to focus on providing the foundations for the professional training of a small number of scientists and engineers. These curricula mostly presented science in a form that focused on providing students with the basic facts, laws or theories related to the various disciplines of science rather than on the broad paradigms and the inter-disciplinary aspects related to epistemic and procedural knowledge. Based on students' ability to master those facts and theories, educators tended to identify students who could continue to study science beyond compulsory education, rather than encouraging every student to be engaged with science.

But scientific and technological advances in today's economies, and the pervasiveness of science- and technology-related issues – from understanding food-safety information to improving local waste-management systems, from tackling antibacterial resistance to improving energy efficiency – have changed that mindset. All citizens, not just future scientists and engineers, need to be willing and able to confront science-related dilemmas.

The PISA framework for assessing science recognises that all young people should have an understanding of science and of science-based technology in order to become informed citizens and to engage in critical discussions about issues that involve science and technology. But lifelong engagement with science, beyond compulsory schooling, requires more than knowledge and skills; students will make the most of their knowledge, and participate in science-related activities, only if they are also positively disposed towards science. This, of course, is particularly important for students who aspire to become scientists or engineers, or to work in other science-related occupations.

It is encouraging that students generally reported positive attitudes towards science. Most students expressed a broad interest in science topics and recognised the important role that science plays in their world. In addition, a large majority of students showed support for scientific approaches to enquiry (such as that sound conclusions are based on repeated experiments). This provides a basis on which teaching and learning science in schools can be built.

Improve both skills and attitudes to encourage lifelong engagement with science

For many countries, Chapter 3 paints a picture of increasing engagement, interest and recognition of the usefulness of science among 15-year-old students. For instance, in Ireland, Poland and the United States, students in 2015 reported significantly greater enjoyment of learning science and greater interest in science than their counterparts in 2006 did. In Ireland, New Zealand, Sweden and the United Kingdom, students in 2015 also reported more often than students in 2006 that they thought that what they learn in school science is useful for their future lives and careers.

These positive changes in attitudes towards science are still modest and too often not accompanied by improvements in students' skills. Nevertheless, they could indicate that greater attention to the affective aspects of learning science can, and does, make a difference.

PISA highlights important differences in young people's skills and attitudes towards science across countries and, within countries, across schools. Volume II (Chapter 2) shows that differences in science performance and in attitudes and



dispositions towards science often correlate positively with differences in the amount of learning time devoted to science. They are also positively correlated with certain teaching strategies used by science teachers in their science lessons, such as providing clear explanations of scientific ideas, guiding students' reflection on how a science idea can be applied to a number of different phenomena, or tailoring the lessons to the students in their classes.

But the assessment provides limited insights into the origin of these differences and into how these skills and attitudes can be improved, both in and outside of school. However, the research literature confirms that teachers play an important role in shaping students' attitudes towards learning science and towards pursuing a science career (Jones, Taylor and Forrester, 2011; Logan and Skamp, 2013; Tröbst et al., 2016; also see Kunter, Baumert and Köller, 2007). While hands-on science experiences, museum visits or participation in informal science labs can expand the opportunities to learn science, the quality of teachers, and the mediating role of parents, instructors or scientists with whom children have a personal exchange is crucial for turning these activities into opportunities to enjoy and value science. Interest, enjoyment, utility and achievement do not develop in isolation, simply by putting activities in front of children.

Successful scientists and engineers often emphasise the important role that their secondary school teachers or their family members played in supporting their decision to become scientists. In a retrospective study based on informal accounts of 37 scientists and engineers, activities such as tinkering, building models, and exploring science independently in and outside of school were viewed as factors that influenced interests in science and engineering (Jones, Taylor and Forrester, 2011).

Longitudinal studies that follow students and their teachers over time have also related the quality of teaching to the development of an initial or lasting interest in science. A German study observed how interest evolved over a short period among more than 2000 elementary and lower secondary students who were taught the same content (evaporation and condensation) by different teachers. The researchers found that the use of everyday contexts in instruction, the clarity of teachers' lessons, the role of student-generated explanations, and the occurrence and quality of experiments could explain a significant share of the increase, or decrease, in student interest observed over this short period (Tröbst et al., 2016). A small case study in Australia followed students from the age of 14 to 17 and showed that interest in science increased, or decreased, as a function of the quality of teaching. The most successful teachers were those whom students perceived as providing clear instructions, emphasising deep understanding of concepts rather than broad coverage of content, posing challenges and striving to make science relevant to students' lives (Logan and Skamp, 2013). Other studies suggest that not only students' interest, but their future performance in university also benefits when high school courses cover less material, but in more depth (Schwartz et al., 2009).

While evidence about the role and characteristics of high-quality teachers continues to accumulate, science educators lament the disconnect between what is known about high-quality teaching and what is commonly practiced. The 19th-century French scientist, Claude Bernard, famously wrote that science is a "superb and dazzling hall, but one which may be reached only by passing through a long and ghastly kitchen".² Osborne, Simon, and Collins (2003), writing more than a century later, comment that "The essential irony of a discipline that offers intellectual liberation from the shackles of received wisdom is that the education it offers is authoritarian, dogmatic and non-reflexive." (Cross-country differences in science teaching, and their association with students' performance and interest in a science-related career are presented in Chapter 2 of Volume II.)

Challenge stereotypes about science-related occupations to help all boys and girls achieve their potential

PISA consistently finds varying levels of engagement with science and expectations of science-related careers across students who are similarly capable and interested in science. In a majority of countries and economies, students from advantaged backgrounds are more likely to expect a career in science – even among students who perform similarly in science and who reported similar enjoyment of learning science.

Gender differences in attitudes also persist. Several actions have been suggested to close this gender gap and, more generally, to encourage more young people, especially those from groups that are now under-represented in science-related fields, to participate in further science-related study and work.

Stereotypes about scientists and about work in science-related occupations (computer science is a "masculine" field and biology a "feminine" field; scientists achieve success due to brilliance rather than hard work; scientists are "mad") can discourage some students from engaging further with science. Schools can counter these stereotypes, and help students



cultivate a wider perspective on science, through better career information (DeWitt and Archer 2015). Students should have access to information that is accurate, credible and avoids unrealistic or exaggerated portrayals. This information should be compiled by independent observers and made available to both parents and students (OECD, 2008; OECD, 2004). Employers and educators in perceived “masculine” or “feminine” fields can also help eliminate existing stereotypes, such as by promoting awareness that computer sciences (“masculine” and “nerdy”) help solve health problems (“feminine” and “caring”) (Wang and Degol 2016), or by reaching out and establishing direct contact with students and schools (OECD, 2008).

Providing objective and reliable career information to both boys and girls, including personal contacts with employers and professionals, can help reduce the influence of informal sources of information, which may lack reliability, solid information and impartiality, and confine choices to the known and familiar (OECD, 2004). PISA data show that students sometimes have a limited understanding of what “a career in science” can mean. Other data show that few pupils have a full or accurate understanding of science-related professions; many are largely unaware of the range of career opportunities that are made available with training in science and technology. What they do know often comes from personal interactions – mostly with their teachers, sometimes with family members – or through the media, where scientists are often portrayed as white men in white coats, and engineers as men performing dirty or dull jobs (OECD, 2008).

But the power of personal interactions can also be harnessed in more formal career guidance activities to counter the stereotyped images that otherwise prevail. Providing all children with opportunities for personal contact with science and engineering professionals, such as through employer talks at school, can help children make informed decisions about their desired education and career path, and has been shown, in some contexts, to have a lasting, positive impact (Kashefpakdel and Percy, 2016).

Other research has shown that the school context also has a lasting influence on how likely girls are to pursue a career in science and engineering. According to a longitudinal study in which students from 250 high schools in the United States were followed from 8th grade (prior to entering high school) until high school graduation, gendered career choices are more frequent in high schools that are characterised by weaker curricula and where boys and girls attend different extracurricular activities (Legewie and DiPrete, 2014). By contrast, in schools that offer advanced mathematics and science curricula, and where extracurricular activities, such as sports clubs, attract both boys and girls in similar number, girls and boys are equally likely to report at the end of high school that they plan to major in a science and engineering field.

Promoting a positive and inclusive image of science is also important. Too often, school science is seen as the first segment of a (leaky) pipeline that will ultimately select those who will work as scientists and engineers. Not only does the “pipeline” metaphor discount the many pathways successful scientists have travelled to reach their career goals (Cannady, Greenwald and Harris 2014; Maltese, Melki and Wiebke 2014), it also conveys a negative image of those who do not end up as scientists and engineers. Because knowledge and understanding of science is useful well beyond the work of scientists and is, as PISA argues, necessary for full participation in a world shaped by science-based technology, school science should be promoted more positively – perhaps as a “springboard” to new sources of interest and enjoyment (Archer, Dewitt, and Osborne 2015). Expanding students’ awareness about the utility of science beyond teaching and research occupations can help build a more inclusive view of science, from which fewer students feel excluded (Alexander, Johnson, and Kelley 2012).

POLICY IMPLICATIONS OF DIFFERENCES IN EQUITY ACROSS COUNTRIES

Equity in education is a matter of design and concerted policy efforts. Achieving greater equity in education is not only a social justice imperative, it is also a way to use resources more effectively, increase the supply of skills that fuel economic growth, and promote social cohesion. As such, equity should be one of the key objectives in any strategy to improve an education system.

PISA 2015 shows that, in most participating countries and economies, socio-economic status and an immigrant background are associated with significant differences in student performance. For example, disadvantaged students (those in the bottom quarter on the PISA index of economic, social and cultural status within their countries/economies) score 88 points lower in science than advantaged students (those in the top quarter on the index), on average across OECD countries. In B-S-J-G (China), Belgium, CABA (Argentina), France, Hungary, Luxembourg, Malta and Singapore, the difference ranges between 110 and 125 score points (Table I.6.3a).

At the same time, up to 34% of disadvantaged students do not attain the baseline level of proficiency in science (Level 2), on average across OECD countries, compared with only 9% of their advantaged peers (Table I.6.6a). Among students with an immigrant background, the likelihood of low performance is more than twice as high among immigrant students as among non-immigrant students, even after taking their socio-economic status into account (Table I.7.5a).



Yet PISA also shows that the relationship between students' background and their outcomes in education varies widely across countries. In some high-performing countries, this relationship is weaker than average – implying that high achievement and equity in education outcomes are not mutually exclusive. This underlines PISA's definition of equity as high performance for students from all backgrounds, rather than as small variations in student performance only. In PISA 2015, Canada, Denmark, Estonia, Hong Kong (China) and Macao (China) achieved both high levels of performance and equity in education.

PISA is an assessment of the cumulative learning that has occurred since birth. Investments in early childhood education bring relatively large returns as children progress through school (Kautz et al., 2014). By contrast, intervening when students have already fallen behind is often more expensive and less effective, even if skills can be developed at all ages. For most countries, comprehensive education policy must also focus on increasing socio-economic inclusion and enabling more families to provide better support for their children's education. For others, it may also mean improving school offerings and raising the quality of education across the board. And most importantly, high levels of equity and performance should be seen as complementary rather than competing objectives.

Design policies based on how well socio-economic status predicts performance and on how much differences in student performance overlap with socio-economic disparities

Policy makers and school administrators often ask themselves whether efforts to improve student performance and equity should be targeted mainly at low performers or at disadvantaged students.

Countries and economies where an equity-centred policy strategy, as opposed to an achievement-centred strategy, would have the greatest impact are those where there are large performance differences between advantaged and disadvantaged students and a strong relationship between performance and socio-economic status. These countries can promote equity and raise their mean level of achievement by implementing policies that target mainly socio-economic disadvantage. In countries with this profile, the steepness of the socio-economic gradient (the average size of the performance gap associated with a given difference in socio-economic status) suggests that low-performing students could rapidly improve their performance if their socio-economic status were also improved. The stronger-than-average relationship between socio-economic status and performance, however, suggests that very few students overcome the barriers to high performance that are linked to disadvantage.

In PISA 2015, Belgium, Singapore and Switzerland were the only three high-performing countries with below-average levels of equity in education outcomes. Austria, the Czech Republic and France also show below-average equity and score around the OECD average. Where both poor performance and low equity are observed, such as in Hungary and Luxembourg, policies that target both low performers and disadvantaged students would reach those who need support the most since, in these cases, they tend to be the same students. Countries and economies where socio-economic status is a strong predictor of performance and where the gap in performance between advantaged and disadvantaged students is wide would benefit from compensatory policies that provide more resources to disadvantaged students and schools than to their advantaged peers.

A second group of countries includes those where there is a strong relationship between performance and socio-economic status but where the differences in performance between advantaged and disadvantaged students are relatively small. This group includes Chile, Peru and Uruguay. More than one in three students in Chile and Uruguay and more than one in two in Peru perform below the baseline level of proficiency in science. In another 14 countries and economies, including Greece, Mexico, Portugal, Spain and the United States, differences in performance are relatively small, but the impact of socio-economic status on performance is around average. In countries and economies 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 students and schools may yield the best results.

A third group of countries and economies are those where performance differences related to socio-economic status are small and there is a weak relationship between student performance and socio-economic status. While these countries/economies tend to show small variation in student performance, their overall levels of achievement can vary greatly. Canada, Denmark, Estonia, Hong Kong (China) and Macao (China) are the only school systems that share above-average performance and above-average equity, whether measured by the strength of the relationship between socio-economic status and performance or by the size of the performance difference across socio-economic groups. Latvia is another high-equity country, but its performance is around the OECD average.



Finland, Japan, Norway and the United Kingdom are also high-achievers with a weak relationship between socio-economic status and performance, but performance differences related to socio-economic status are around average. Beyond universal policies, these countries may consider policies targeted to low performers who may not necessarily be defined by their socio-economic status (for example, immigrant students), or to poor-performing schools, when differences between schools are large.

In another 15 countries that score below average in science, including OECD countries Iceland, Italy and Turkey, socio-economic status is only weakly related to performance, and the differences in performance between advantaged and disadvantaged students are relatively small. In all these countries except Iceland, Italy and the Russian Federation (hereafter “Russia”), more than one in four students performs below the baseline level of proficiency in science. Equity indicators suggest that, in many of these countries, many low-performing students may not come from disadvantaged backgrounds. Thus, by themselves, policies that specifically target disadvantaged students would not address the needs of many of the country’s low performers. As is true in high-performing systems, in these countries, universal policies that reach all students and schools, or policies targeted to low-performing schools, regions or other groups not necessarily defined by socio-economic status, are likely to have more of an impact in improving performance while maintaining high levels of equity.

Target special resources to schools with a high concentration of low-performing and disadvantaged students.

In PISA 2015, and in line with previous assessments, performance differences between schools account for slightly less than a third of the overall variation in performance, on average across OECD countries (Table I.6.9). But the extent of between-school differences in performance varies widely across school systems. In high-performing systems where between-school differences are small – as it is the case in Canada, Denmark, Finland, Ireland, Norway and Poland – students can be expected to achieve at high levels regardless of which school they attend.

By contrast, in high-performing countries where between-school variation is above the OECD average, notably B-S-J-G (China), Belgium, Germany, the Netherlands and Slovenia, the school’s socio-economic profile is a stronger predictor of student performance. In these countries/economies, differences in mean performance between advantaged and disadvantaged schools are larger than 140 score points in science – that is, about 40 points above the OECD average (Table I.6.11). And in a larger number of countries and economies with below-average performance, most notably in Bulgaria, CABA (Argentina), Hungary, Luxembourg and Peru, socio-economic status also accounts for a large share of the between-school variation in science performance. Once again, this translates into large differences in the mean performance between students attending advantaged schools and those enrolled in disadvantaged schools.

There are two main policy options to address this situation. One is to try to reduce the concentration of disadvantaged and low-performing students in particular schools. PISA shows that, at the system level, more socio-economic inclusion in schools is related to smaller shares of low performers and larger shares of top performers (OECD, 2016). This suggests that policies leading to more social inclusion within schools may result in improvements among low-performing students, without adversely affecting high performers. In education systems that allow parents and students to choose their schools, greater socio-economic diversity in schools can be promoted through regulatory frameworks, better dissemination of information about the available choices and financial incentives. Legislation could guarantee that public and private schools receiving public funding are open to all students regardless of their socio-economic status, prior achievement or other personal characteristics. Chile adopted such policy in its 2009 General Education Law (OECD, 2015a). Education systems might also set admissions quotas for disadvantaged students to ensure that they are represented in all schools. For example, while the French Community of Belgium grants parents a large degree of choice in choosing a secondary school for their child, in oversubscribed schools, around 20% of places are reserved for students who had attended disadvantaged primary schools (OECD, 2013b).

A second policy is to allocate more resources to schools with larger concentrations of low-performing students and to disadvantaged schools. In more than 30 of the countries/economies that participated in PISA 2015, students in advantaged schools have access to better material or human resources than their peers in disadvantaged schools, although this is not the case in all countries with larger-than-average between-school disparities in performance. For instance, the Netherlands makes extensive use of early tracking and has the highest percentage (68%), among OECD countries, of variation in students’ science performance between schools. However, there are no differences in the degree of concern about educational resources between principals of advantaged schools and principals of disadvantaged schools. The Dutch system combines an equitable allocation of funds to all schools receiving public funding with targeted block grants for schools serving disadvantaged students and for special purposes, such as preventing school dropout (see Box 5.2 in Volume II).



In cases where disparities in resource allocation between schools of different socio-economic profiles stem from residential segregation, giving higher-level authorities responsibility for resource allocation and strengthening their capacity to monitor and support schools at risk can begin to address the problem. Other options include allocating specific goods and/or personnel to disadvantaged schools, including teachers specialised in target subjects and/or with training of particular relevance for low-performing students, providing other professional and administrative staff, and instructional materials (e.g. computers, laboratories, libraries) or improving school infrastructure. For example, Ireland's Delivering Equality of Opportunity in Schools programme is a national plan that identifies socio-economic disadvantage in schools based on the community in which they are located, and provides different kinds of resources and support, depending on the degree of disadvantage (OECD, 2015a).

Beyond measures to promote greater socio-economic inclusion and compensatory resource allocation mechanisms, policies need to draw from successful school-level practices to promote science literacy. A study covering the entire population of ninth-grade students in Sweden and examining their probability of applying to the Swedish Natural Science Programme (NSP) – a preparatory programme for tertiary studies in scientific fields – found that about 10% of the schools in the country deviated from predictions about the number of applicants based on their socio-economic status. More than half of the schools considered succeeded in compensating for the socio-economic status of their students and boosting their interest in the programme (Anderhag et al., 2013). Identifying successful “outliers” is a first step for closer investigation into teaching and school leadership practices that can make a difference.

Encourage positive attitudes towards learning science among students of all backgrounds.

While PISA 2015 provides an encouraging picture about the levels of engagement with science and support for scientific approaches to enquiry among 15-year-olds in many OECD and partner countries, results also highlight differences in attitudes toward science that are related to socio-economic status. An area where these differences are most apparent are students' expectations to work in a science-related occupation by the age of 30, which indicates 15-year-olds' plans for choosing a scientific field of study in post-secondary education. In more than 40 countries and economies, and after accounting for students' performance in the science assessment (a strong correlate of career expectations), disadvantaged students remain significantly less likely than their advantaged peers to see themselves pursuing a career in science. In the OECD countries Finland and Poland, disadvantaged students are half as likely to expect such a career as their advantaged peers – even if they score similarly in science. In addition, in virtually all PISA-participating countries and economies, advantaged students tend to believe more strongly than disadvantaged students in the value of scientific approaches to enquiry (Table I.6.8).

The main policy implication of these findings is that, in order to foster positive dispositions towards science and promote greater socio-economic diversity among students who go on to pursue scientific careers, school systems need to focus on the psychological and affective factors associated with science performance. Specific programmes might be needed to spark interest in science among students who may not receive such stimulation from their family, and to support students' decision to pursue further studies in science.

The most immediate way to foster interest in science among students with less supportive home environments may be to increase early exposure to high-quality science instruction in schools. A survey of students in urban public schools in Israel found that differences in the interest in pursuing STEM fields in tertiary education related to family background disappear among students enrolled advanced science courses in secondary school (Chachashvili-Bolotin, Milner-Bolotin and Lissitsa, 2016). Museums and science centres could be unofficial partners in this effort. Ethnographic research in the United Kingdom suggests that informal science education institutions could do better at designing programmes that match the levels of knowledge, language skills, and financial capacity of youth from disadvantaged and immigrant backgrounds (Dawson, 2014). To become more inclusive, informal science education institutions may need to welcome – and seek out – visitors from a wider range of social, cultural and linguistic backgrounds.

Reduce differences in exposure to science content in school by adopting rigorous curriculum standards

Inequity in opportunity to learn can translate into significant differences in performance in any subject, but PISA 2015 finds that differences in instruction time related to differences in students' backgrounds are more pronounced in science than in reading or mathematics. The amount of time that students are exposed to science content in the classroom is indeed a key component of opportunity to learn science. On average across OECD countries, a larger percentage of advantaged students than disadvantaged students attends at least one science lesson in school every week. As a result of these differences, advantaged students might be exposed to around 20 more hours of science instruction than their disadvantaged peers (Table I.6.15).



The reasons why students of difference socio-economic status receive more or less instruction in science can, of course, be related to the choices they are given, but also to policies that sort students into different grades or study programmes with varying academic content. In PISA 2015, and after accounting for differences in performance, disadvantaged students are almost twice as likely as advantaged students to have repeated a grade by the time they sit the PISA test – which means they probably have not covered more advanced science content by the age of 15 – and are almost three times more likely to be enrolled in a vocational rather than an academic track – which might also mean that science content is covered in less depth (Tables I.6.14 and I.6.16).

A potential policy response to increase equity in opportunity to learn is to reduce or delay student sorting practices, including early tracking and other forms of ability grouping, that may limit exposure to academic content.

A complementary policy is to adopt robust curricular standards for all students, no matter which school they attend. Shared standards and high-quality, standard-aligned instructional materials can help to ensure that every student develops a baseline levels of skills and is prepared for advanced science coursework and, eventually, post-secondary science-related studies or work. Implementing rigorous and consistent standards across all classrooms does not mean limiting the curricular and pedagogical choices of schools, but rather that the same minimum standards are met by all schools, regardless of their socio-economic intake and specific study programmes. For example, in 2004, Germany introduced common education standards in different subjects, including biology, chemistry and physics. These standards have ensured greater coherence across Germany's three-track school system, leading to more academic content in the *Hauptschule* and *Realschule* vocational tracks (OECD, 2013a).

EDUCATION POLICIES TO SUPPORT IMMIGRANT STUDENTS

The policies and practices that countries design and implement to support immigrant students have a major influence on whether integration in the host communities is successful or not. How well immigrant students do at school is not only related to their attitudes, socio-economic status and prior education, but also to the quality and receptiveness of the host country's education system.

More than one in ten students (12.5%) in PISA 2015 have an immigrant background. Global migration flows mean not only that the proportion of immigrant students has been growing across PISA assessments, but also that this population has become increasingly diverse across host countries (Tables I.7.1 and I.7.2). On average across OECD countries, immigrant students score lower than their non-immigrant peers in all subjects assessed and are more likely not to attain the baseline level of proficiency (Level 2) (Tables I.7.4a-c and I.7.5a-c). Yet immigrant students are 50% more likely than their non-immigrant peers who perform similarly in science to expect to work in a science-related career by the age of 30 (Table I.7.7). And the difference in science performance between immigrant and non-immigrant students narrowed by 6 score points since PISA 2006. In 2015, socio-economic status and familiarity with the language of instruction and assessment in host countries accounted for about 40% of that difference, on average across OECD countries (Table I.7.15a).

But the outcomes of immigrant students vary widely across countries and economies, depending not only on their socio-economic status and national origin, but also on the characteristics of the school systems of the destination countries. A key policy question is how best to best support immigrants students who face the multiple disadvantage of socio-economic deprivation, low education standards in their countries of origin, and cultural adjustment to host countries, including learning a new language. How, too, can destination countries/economies support the high aspirations of immigrant students and families, and channel the high levels of skills that many of them bring? Previous OECD work describes various education policies that have proven effective in helping immigrant students succeed in school (Nusche, 2009; OECD, 2010; OECD, 2015b).

Short-term, high-impact policy responses

A quick-win policy response is to provide sustained language support for immigrant students with limited proficiency in the language of instruction. Language skills are essential for most learning processes; any student who does not master the language used in school is at a significant disadvantage. Common features of successful language-support programmes include sustained language training across all grade levels, centrally developed curricula, teachers who are specifically trained in second-language acquisition, and a focus on academic language and integration of language and content learning. Since language development and general cognitive development are intertwined, it is best not to postpone teaching of the main curriculum until students fully master their new language. One way to integrate language and academic learning is to develop curricula for second-language learning. Another is to ensure close co-operation between language teachers and classroom teachers, an approach that is widely used in countries that seem most successful in educating immigrant students, such as Australia, Canada and Sweden (Christensen and Stanat, 2007).



Offering high-quality early childhood education, tailored to language development, is another immediate policy response. Entering early education programmes can improve the chances that immigrant students start school at the same level as non-immigrant children. Improved access to pre-primary education may involve offering programmes free of charge to disadvantaged students and linking enrolment to wider social policy programmes to support the integration of immigrant families. To raise awareness of the value of early learning and overcome potential reluctance to enrol children, targeted home visits can help families support their child's learning at home and can also ease entry into appropriate education services.

A third high-impact policy option is to build the capacity of schools receiving immigrant children, as the successful integration of immigrant children depends critically on having high-skilled and well-supported teachers. This can involve providing special training for teachers to better tailor instructional approaches to diverse student populations and to support second-language learning, and also, more generally, reducing teacher turnover in schools serving disadvantaged and immigrant populations, and encouraging high-quality and experienced teachers to work in these schools. Hiring more teachers from ethnic minority or immigrant backgrounds can help reverse the growing disparity between an increasingly diverse student population and a largely homogeneous teacher workforce, especially in countries where immigration is a more recent phenomenon.

Medium-term, high-impact policy responses

Among policy responses with a medium-term horizon is avoiding the concentration immigrant students in the same, disadvantaged schools. Schools that struggle to do well for domestic students will struggle even more with a large population of children who cannot speak or understand the language of instruction. Countries have used three main ways to address the concentration of immigrant and other disadvantaged students in particular schools. The first is to attract and retain other students, including more advantaged students. The second is to better equip immigrant parents with information on how to select the best school for their child. The third is to limit the extent to which advantaged schools can select students on the basis of their family background.

A second set of options is related to limiting the application of stratification policies, including ability grouping, early tracking and grade repetition. Tracking students into different types of school programmes, such as vocational or academic, seems to be especially harmful for immigrant students, particularly when it occurs at an early age. Early separation from mainstream students might prevent immigrant students from developing the linguistic and culturally relevant skills needed to perform well at school.

Policy can also provide extra support and guidance to immigrant parents. This can take the form of engaging in stimulation-oriented interactions, such as reading to and having discussion about school with children, but also of helping to orient student choices and navigate the school system. While immigrant parents often have high aspirations for their children, parents may also feel alienated and limited in their capacity to support children if they have poor language skills or an insufficient understanding of how schools in the host country function. Programmes to support immigrant parents can include home visits to encourage these parents to participate in educational activities, employing trained liaison staff to improve communication between schools and families, and reaching out to parents to involve them in school-based activities. Evidence from an intervention in a disadvantaged school district in France shows that low-cost programmes can boost parents' involvement in their children's education and improve student behaviour at school (Avvisati et al., 2014).



Notes

1. www.dailymail.co.uk/health/article-3850014/Revolutionary-new-toothpaste-not-removes-plaque-save-heart-attack.html; www.dailymail.co.uk/health/article-3849596/A-pill-cure-autism-Study-identifies-defect-sufferers-cells-treated-existing-medication.html; www.dailymail.co.uk/health/article-3848452/A-glass-red-wine-day-polycystic-ovaries-bay-Compound-grapes-nuts-corrects-hormone-imbalance-women-PCOS.html (accessed 19 October 2016).
2. “S’il fallait donner une comparaison qui exprimât mon sentiment sur la science de la vie, je dirais que c’est un salon superbe tout resplendissant de lumière, dans lequel on ne peut parvenir qu’en passant par une longue et affreuse cuisine.” (Bernard 1865), p.28.

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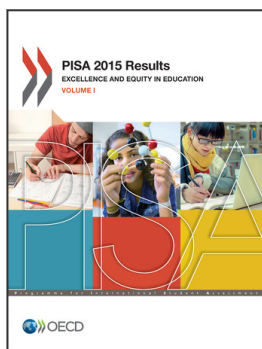
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