3

Experiences, Attitudes and Motivations for Excellence

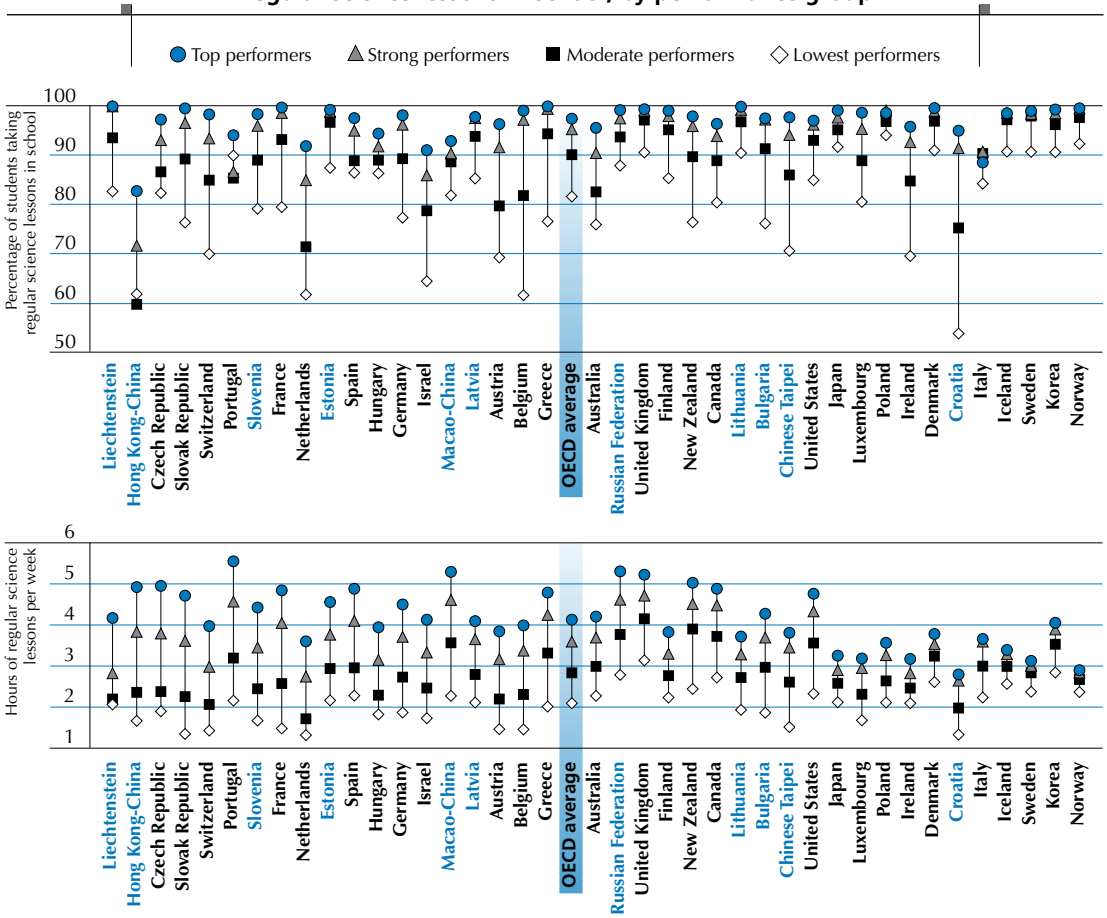
Having looked at individual and school characteristics of top performers in science, this chapter turns to the analysis of student experiences, attitudes and motivations. It investigates differences among performance groups and identifies what characterises top performers in science. The chapter is divided into four sections: The first describes student experiences with science teaching and learning as they relate to top performance; the second analyses the motivations of top performing students; the third reviews the aspirations of top performers in science for a future career in science; and the fourth and final section analyses a particular group of top performers in science, those relatively unmotivated.

HOW DO TOP PERFORMERS EXPERIENCE THE TEACHING AND LEARNING OF SCIENCE?

Do top performers spend more time in school learning science?

Previous analysis has shown that student time spent in regular lessons at school is positively related to student performance (OECD, 2007). It is therefore worth comparing the amount of time top performers in science devote to studying science at school with the time put in by other performance groups, especially strong performers. Figure 3.1a provides information reported by students on the amount of time spent in science lessons at school.

Figure 3.1a
Regular science lessons in school, by performance group



Countries are ranked in descending order of the difference in the hours between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.1a.

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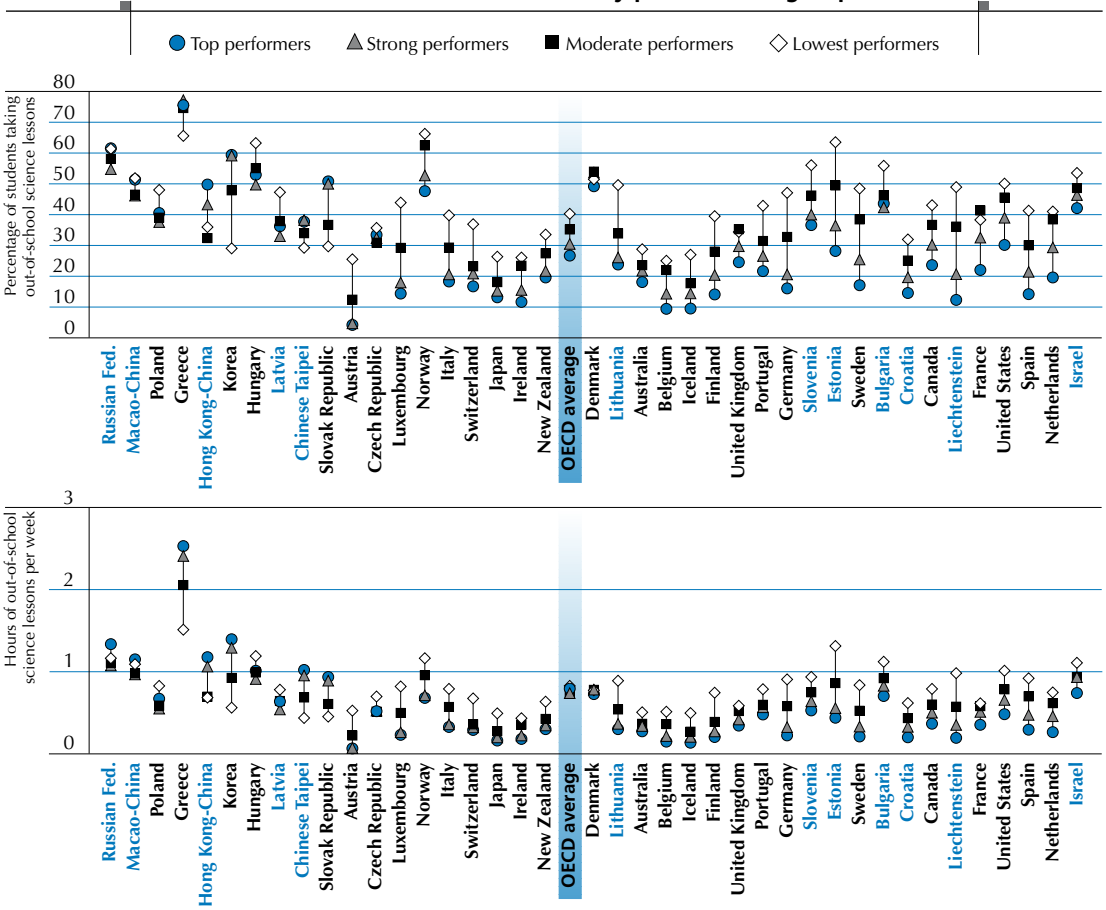
The figure shows that top performers in science receive more science instruction than any other group. When compared with the lowest performers in science, for the OECD countries, top performers in science receive about two extra hours per week of instruction in science. Top performers in science receive on average four hours of instruction per week and the lowest performers only two. It is possible that students with lower proficiency, gave priority to subjects other than science. Another possibility is that the students themselves are allowed to choose science courses as electives and those who have done poorly in science or do not like science choose to take fewer courses. When compared with strong performers, top performers receive an extra half an hour of instruction per week. This type of difference is even found in countries with the largest proportions of top performers such as Australia, Canada, Finland, Japan and New Zealand. In the Czech Republic, the Slovak Republic, Switzerland and Portugal the top performers received about an hour or more of science per week than the strong performers (Figure 3.1a).

Clearly, in all countries scrutiny should be given to exposure to science as one possible explanation for differences in student outcomes. Moreover, if these differences are found among 15 year olds, it is likely that even larger differences will be found at the older ages where science is most likely no longer compulsory and becomes an elective.

Figure 3.1b
Out-of-school science lessons, by performance group



Countries are ranked in descending order of the difference in the hours between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.1b.

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Do top performers spend more time in science lessons outside of school?

One way in which families might choose to improve the science performance of their children is to obtain assistance through science instruction outside of the school. Such instruction could be used to raise the science performance of students who were doing poorly or to provide additional enrichment for those students who are doing well. For this reason, it is a priori not clear what patterns of out-of-school tuition might be found among the different performance groups.

Figure 3.1b shows that students with lower science performance were generally receiving more out-of-school lessons in science than those with higher performance, although the absolute levels and differences among the performance groups are modest. For the OECD countries, on average, lowest performers were getting about 45 minutes a week of such instruction; at the other end of the scale the top performers were obtaining half an hour or less of such instruction. Thus, although lowest performers are receiving more out-of-school instruction in science, it is only a difference of 15 minutes per week and does not come close to compensating for the additional two hours per week of school instruction in science that the top performers receive on average.

Understanding the nature of out-of-school lessons is important, and this nature may not just vary between students and schools, but also across countries. For example, two important exceptions to the pattern of less time spent on out-of-school science lessons among the top performers are Greece and Korea. In these two countries top performers reported that they were receiving about an hour more of out-of-school science lessons each week relative to the lowest performers (Figure 3.1b).

How do top performers describe their science lessons?

Some approaches to science teaching may prove more effective than others in motivating students, imparting knowledge and engaging students in scientific activities. PISA 2006 attempted to ascertain whether there was a link between particular approaches to science instruction and science outcomes by collecting a very rich set of information on approaches to science teaching. The pedagogical emphasis in recent years has been away from a narrow focus on memorisation toward such instructional approaches as hands-on experimentation, testing of ideas, development of scientific explanations for real-world events and interactions with other students to explore phenomena.

PISA used the student questionnaire to examine student experiences with respect to science teaching and learning. In this respect it developed a rich set of information on the practices of science classes as experienced by students both within and among countries. Although this data has value in itself in considering teaching practices and whether they match desired policies, they apply only to the experience that the students have had in their present schools. Since the relation between these instructional practices and students' scientific proficiencies would have to be assessed by the cumulative effect of practices over the entire schooling experience, and not on the basis of what is usually a single science teacher for one year or less, it is difficult to relate these temporal data to science performance. However, the following section will attempt to describe the instructional techniques reported by students in the four different performance groups.

PISA sought information that enabled the construction of four indices on teaching strategy. These identified whether students were experiencing strategies focused on models or the application of science, or those focused on scientific investigations, on hands-on experiences and on allowing students to discuss their ideas and understandings.

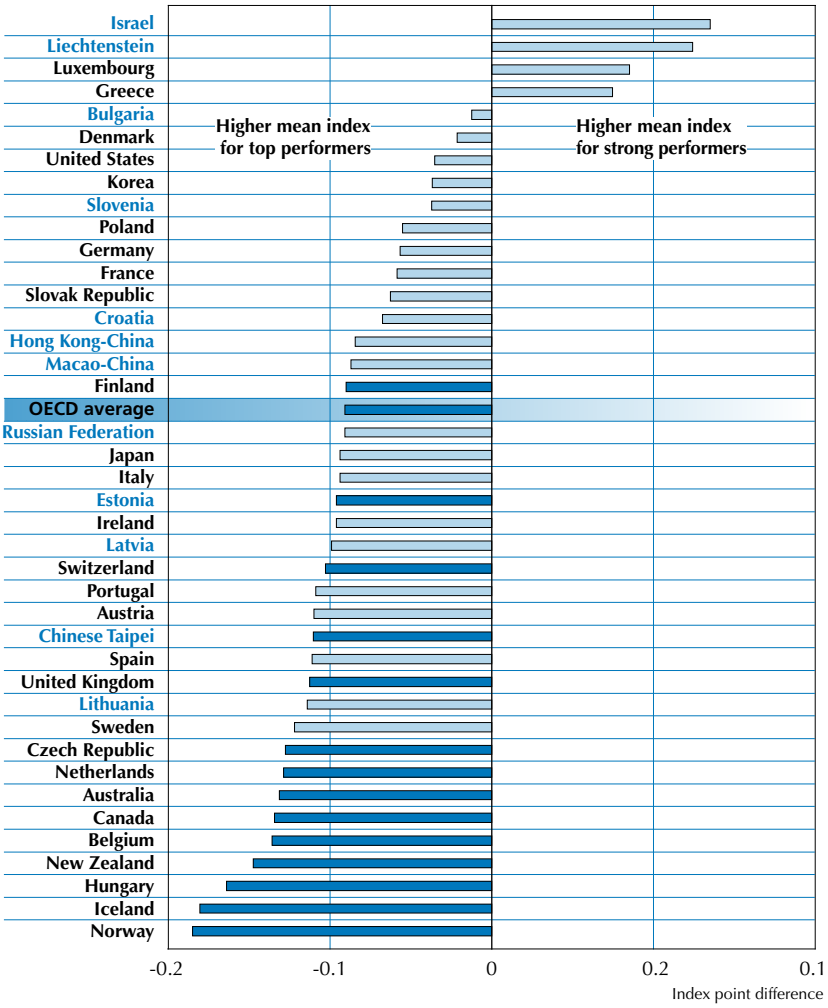
Students ought to understand how science is used to solve specific challenges as well as understanding scientific explanations for familiar phenomena in daily life. Education systems strive to give students insights into how they might use scientific understanding as citizens, workers, inventors, innovators and other potential roles. Table A3.2a and Figure 3.2 show results for the *index of focus on models or applications in*

science teaching and learning. This index was calculated using students' responses to questions regarding the teachers' attempt to use examples of technological and scientific applications relevant to students' lives and society as well as how scientific principles can be applied to many different phenomena.

Across OECD countries, there is a modest increase in index values for focus on models or applications in science teaching and learning from about minus –0.05 for lowest and moderate performers, to 0.04 for strong performers and 0.13 for top performers. This increase represents a boost from the lowest to the top levels of performance of about one-fifth of a standard deviation in use of models or applications in science lessons. For individual countries this modest pattern also seems to hold with top performers likely to report more focus on models or applications in their science lessons. In 12 of the 28 OECD countries with sufficient data, more top performers report exposure to models or applications of science in their classes, compared to strong performers.

Figure 3.2

Top and strong performers' perception of the science teaching strategy focus on application



Note: Significant differences are highlighted with a dark tone.
Source: *OECD PISA 2006 Database*, Table A3.2a.

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Students were also asked to indicate the frequency of other types of instruction such as doing scientifically oriented investigations, obtaining hands-on experiences such as practical experiments, and interacting with other students to discuss their ideas and scientific understanding (Tables A3.2b, c and d). In the case of the use of investigation as an instructional strategy, OECD countries' top performers were exposed to less investigation than students at lower levels of science performance. Similarly, top performing students reported lower levels of student interaction in their science lessons.

The interpretation of these results is challenging. It is possible that schools view the traditional approach of focussing on applications as the most effective one for teaching science to high achievers. Also, the more engaged approaches of investigation, hands-on activities and student interactions may be viewed as effective in getting lower achieving students to take a greater interest in science by giving them more freedom to explore and encouraging social interactions with other students. Further inquiry is necessary both to understand the underlying reasons for these patterns of instruction by performance group as well as to understand their consequences. It is possible too that effective teaching and learning takes place with a mix of different types of lessons – including some hands-on activities, some research, some discussion and some teacher-centred lessons.

Do top performers pursue science-related activities?

Engaging in activities outside of school or in conjunction with school activities, students can add to or reinforce their science learning. These activities may be pursued out of curiosity rather than any instrumental intentions for learning. That is, they may simply be entertaining pastimes or vehicles for responding to curiosity or wonder.

The PISA 2006 survey asked students how often they pursued the following activities: watching TV programs about science; obtaining books on scientific topics; visiting websites on scientific topics; listening to radio programs about advances in science; reading science magazines or science articles in newspapers; and attending a science club. For each potential type of science activity, the students were requested to indicate the frequency of engagement: very often, regularly, sometimes, or never or hardly ever. These responses were constructed into the *index of students' science-related activities*.

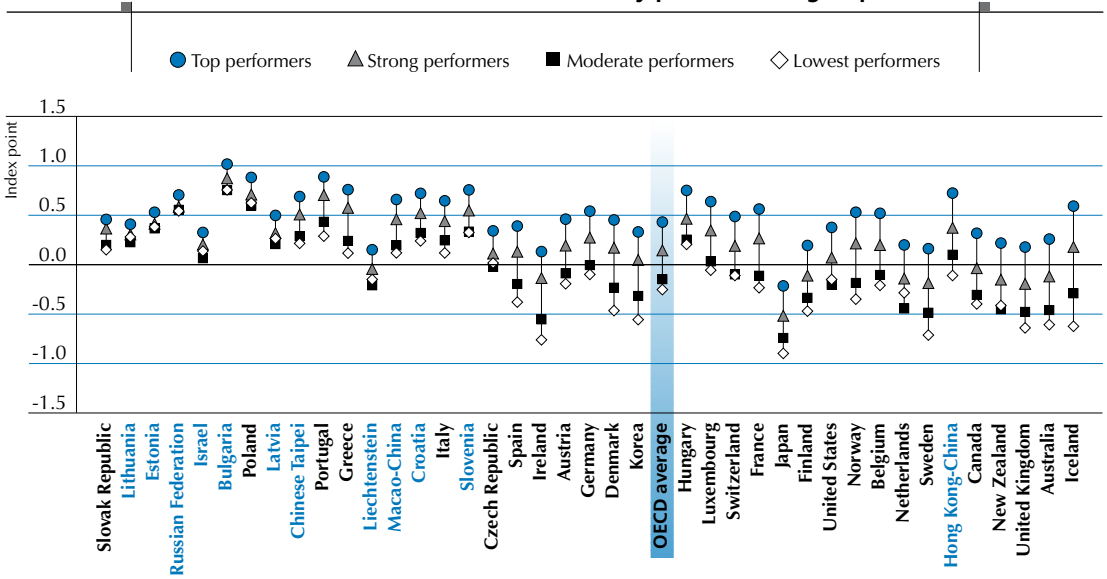
In the initial analysis of PISA 2006 data, it was found that across countries only a minority of students reported that they regularly or very often engaged in science-related activities. Results indicate that print and television media have the most influence over students in communicating information about science beyond the classroom (OECD, 2007).

Top performers in science engage in science-related activities relatively more often than any other performance group. In particular, on average across the OECD countries, 38% reported reading science magazines or science articles in newspapers regularly or very often and 32% reported watching TV programmes about science regularly or very often. Only 13% and 18% of lowest performers reported engaging in these activities. Compared to students in the other performance groups, slightly higher percentages of top performers reported visiting websites about science topics (21%) or borrowing or buying books on science topics (14%) regularly or very often. The other science-related activities that students were asked about were not very popular as regular activities: less than 10% of students in each of the four performance groups reported listening to radio programmes or attending science clubs regularly or very often, on average across the OECD countries (Table A3.3b).

Overall, there is a strong and direct relationship between science performance and frequency of participation in student-initiated science activities in each of the OECD countries. Figure 3.3 shows results for each of

the performance groups on the *index of science-related activities*. Across the OECD countries on average top performers were almost two thirds of a standard deviation above the lowest performers in participating in these activities, a large difference. Also, top performers were a quarter or more of a standard deviation above the strong performers, a difference that is moderately large and statistically significant. Significantly more top performers than strong performers reported pursuing science-related activities on a regular basis in all countries, except Greece, the Slovak Republic, and the partner countries Bulgaria, Israel, Liechtenstein, Lithuania and the Russian Federation.

Figure 3.3
Student science-related activities, by performance group



Countries are ranked in ascending order of the difference in the mean index between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.3a.

Because they mostly take place outside of the school environment, some of these science activities are likely to be associated with students' socio-economic background. Given the strong link between science performance and socio-economic status, it is possible that the observed relationship between student performance and student-initiated science activities is confounded by the fact that both are related to students' socio-economic background. Accordingly, an adjustment was made for students' socio-economic background it was found that all countries, for which there are adequate data, except the partner economy Macao-China, continue to show a statistically significant difference between top performers and strong performers. Even after adjusting for students' socio-economic background, the top performers are a quarter of a standard deviation above the strong performers in student-initiated science activities across the OECD countries. Given the large statistical impact of socio-economic background on student performance, it is rather remarkable that student-initiated science activities continue to maintain such a strong statistical relationship with performance after adjustment for socio-economic background.

Several interpretations are plausible for these results. One possibility is that some of the top performers in science excel because of their active participation in science-related activities outside of school. An alternative explanation is that some of the top performers have a greater interest in science and ability

to understand scientifically-based events outside of the school and therefore they are likely to report undertaking these activities more frequently. Policy makers may explore ways of encouraging all students to engage in science-related activities outside of school with the aim of helping strong performers to excel and become top performers, in turn improving the average science performance of all students.

As part of the PISA 2006 assessment, 16 countries complemented the perspectives of students and school principals with data collected from parents.[1] PISA asked students' parents how often their child would have done the following things when the child was about 10 years old: watched TV programmes about science; read books on scientific discoveries; watched, read or listened to science fiction; visited websites about science topics; and attended a science club. From these six questions, an index was constructed to measure students' activities related to science at age 10. In ten of the 16 countries and economies, Iceland, Portugal, Luxembourg, New Zealand, Korea, Italy, Denmark, Germany, and the partner countries and economies Hong Kong-China and Croatia, the parents of top performers reported that their children had done these science-related activities more frequently than did the parents of strong performers (Table A3.3c).

ARE TOP PERFORMERS ENGAGED AND CONFIDENT SCIENCE LEARNERS?

Student experiences and dedication are important drivers of performance and so are student attitudes and motivations. To what extent do the top performers in science enjoy learning science at school? How interested are they in different science topics? Do they generally have fun in their science lessons? Further, are they motivated to do well in science? This section examines evidence collected by PISA from students on these issues.

Which science topics are top performers interested in?

Interest in a subject can influence the intensity with which a student engages in learning. To measure students' general interest in science and their interest in specific science topics in PISA 2006 they were asked a set of questions on: their level of interest in several different subjects, including human biology, astronomy, chemistry, physics, the biology of plants and geology; their general interest in the ways in which scientists design experiments; and their understanding of what is required for scientific explanations. Students could give one of the following answers: "high interest", "medium interest", "low interest" or "no interest". Interested students are those reporting either high or medium interest in the given topics. An *index of general interest in science* was calculated using the responses to these questions.

Initial analysis of the PISA 2006 results showed that while the majority of students across the OECD countries (68% on average) reported an interest in human biology, there was less interest in astronomy, chemistry, physics, the biology of plants and the ways in which scientists design experiments (between 46 and 53% on average). Even smaller proportions of students reported interest in what is required for scientific explanations and in geology (36 and 41% on average, respectively). Is this also the case among top performers in science?

Top performers in science show higher levels of interest in science than any other group, including strong performers. When comparing levels of interest reported by students in the different performance groups, top performers in science were much more likely to show a general interest in science compared to other students, including even the strong performers (index values of 0.45 and 0.21, respectively, on average across the OECD countries). Differences between the top performers and the strong performers were observed in all OECD countries except Greece and the Slovak Republic (Table A3.4a).

At least 50% of top performers on average across the OECD countries reported being interested in all the science topics they were asked about (Table 3.1). On average across the OECD countries, 77% of the top performers reported interest in human biology, this figure being over 80% of the top performers in Greece, France, Ireland, Belgium, the United Kingdom, Poland, Italy and Germany, as well as in the partner

countries and economies Hong Kong-China, Lithuania, Bulgaria, Croatia and Macao-China. Top performers were comparatively less interested in the biology of plants (56% on average across the OECD countries), although 71% of the top performers in France were interested in this. Chemistry was also of interest to the majority of top performers across the OECD (72% on average) and particularly in Portugal, France, Norway, Canada and Luxembourg (at least 80% of top performers). Sixty-nine percent of top performers on average across OECD countries were interested in physics, with the highest percentages in France (85%) and Norway (84%). Contrary to the OECD average percentages, therefore, the top performers in PISA report high levels of interest in not just human biology, but also chemistry and physics.

Table 3.1
Interest in different science topics and enjoyment of science

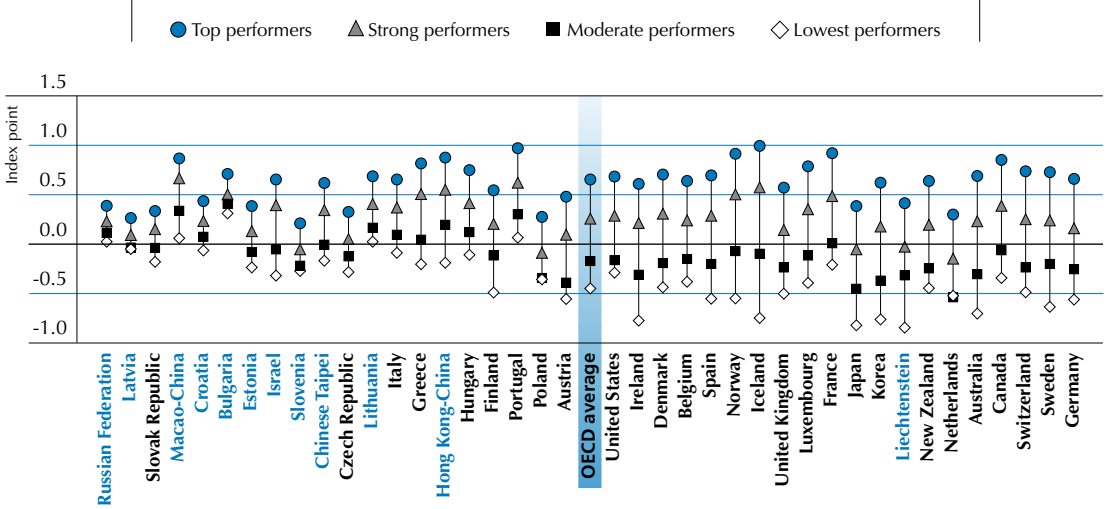
Average percentage of students by performance group in OECD countries reporting high or medium interest in the following:				
Interest in different science topics	**Lowest performers**	**Moderate performers**	**Strong performers**	**Top performers**
	%	%	%	%
Human biology	56	67	74	77
Topics in chemistry	37	45	59	72
Topics in physics	39	44	57	69
Topics in astronomy	36	50	62	67
Ways scientists design experiments	38	43	50	58
The biology of plants	38	44	51	56
Topics in geology	29	37	47	52
What is required for scientific explanations	29	32	41	51
Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:				
Enjoyment of learning science	**Lowest performers**	**Moderate performers**	**Strong performers**	**Top performers**
	%	%	%	%
I enjoy acquiring new knowledge in science.	49	62	78	87
I am interested in learning about science.	46	57	73	85
I generally have fun when I am learning science topics.	48	57	72	83
I like reading about science.	33	43	60	75
I am happy doing science problems.	30	37	53	68

Do top performers enjoy learning science?

Initial PISA 2006 results indicated that in general students enjoy learning science (OECD, 2007). However, do the levels of enjoyment reported by students vary among the performance groups? Figure 3.4 and Table 3.1 present the results for the *index of enjoyment of science* for each of the performance groups. To measure students' enjoyment of science in PISA 2006, students were asked to indicate their level of agreement with five statements: *i)* I enjoy acquiring new knowledge in science; *ii)* I am interested in learning about science; *iii)* I generally have fun when I am learning science topics; *iv)* I like reading about science; and *v)* I am happy doing science problems. A four-point scale with the response categories "strongly agree", "agree", "disagree" and "strongly disagree" was used. The *index of enjoyment of science* was calculated from students' answers to these questions.

Top performers in science show particularly high levels of enjoyment of science. The results show a high degree of divergence in enjoyment of science among the performance groups with top performers reporting much greater levels of enjoyment of science than those at lower levels of performance. For example, over 80% of the top performers reported that they enjoy acquiring new knowledge in science, are interested in learning about science and generally have fun when learning science. However, this was the case for less than 50% of the lowest performers (Table 3.1).

Figure 3.4
Enjoyment of science, by performance group



Countries are ranked in ascending order of the difference in the mean index between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.5a.

Top performers also seem to enjoy a learning challenge: 68% on average across the OECD countries reported that they are happy doing science problems. The corresponding figure for strong performers was only 53%. Indeed, top performers reported higher levels of enjoyment of science than strong performers in all countries (differences were in the range of 17% to 49% of a standard deviation [Table A3.5a]) except the partner countries Bulgaria and the Russian Federation. Furthermore, science enjoyment and engagement in science-related activities are highly correlated in most countries (Table A3.5a).

The conclusion is that enjoyment of science has a close relationship to science performance whether as a cause or consequence. To the degree that enjoyment is at least partially a cause of student proficiency in science, it would seem that countries should set a high priority on exploring and designing strategies to enable students to enjoy science.

How important is it for top performers to do well in science

Top performers both enjoy learning science at school and are interested in core science subjects. But do they value science? How important is it for top performers to do well in science?

Top performers in science report being motivated to learn science because they believe it will help them with their future studies or career. Table 3.2 summarises the results for the average percentages of students on statements concerning their *instrumental motivation to learn science*. Values on the index were calculated from students' levels of agreement with each of five statements (see Table 3.2). On average across the OECD countries, the majority of top performers reported that they study science because they know it is useful for them (81%), because what they learn will improve their career prospects (76%) or they need it for what they want to study later on (70%). There were marked differences in levels of instrumental motivation to learn science reported by top performers and by students in the other performance groups. There were significant differences between top performers and strong performers in all OECD countries except Greece and Portugal (Table A3.6a and b).

Table 3.2
Instrumental motivation to learn science and the importance of doing well in science

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:

Instrumental motivation to learn science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I study science because I know it is useful for me.	55	62	73	81
Studying my science subject(s) is worthwhile for me because what I learn will improve my career prospects.	52	56	67	76
Making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on.	58	58	66	75
What I learn in my science subject(s) is important for me because I need this for what I want to study later on.	51	50	58	70
I will learn many things in my science subject(s) that will help me get a job.	51	52	59	67

Average percentage of students by performance group in OECD countries reporting that it is VERY IMPORTANT to do well in each subject:

The importance of doing well in science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
Mathematics	50	54	60	65
Science	20	23	34	47
Reading	55	54	49	43

The proportion of top performers in science reporting that doing well in science is very important to them can be an indicator of the academic importance of science to students, beyond whether the subject is of interest to them or whether they enjoy their science lessons. Taken together with the degree of importance they attribute to mathematics and test language subjects, this can also indicate the relative importance of science to top performers. Students were asked to report how important it is in general for them to do well in science, mathematics and test language subjects. They could give one of four possible answers: "very important", "important", "of little importance" or "not important at all".

Table 3.2 shows that among science top performers, the most important subject for them to do well in is mathematics. Across the OECD countries, 65% of science top performers on average reported that doing well in mathematics is very important to them. This compared with 47% indicating that science is very important to them and 43% indicating that test language subjects were very important to them. Moreover, science is of relatively less academic importance than the other two subject areas to students in other performance groups. At least 50% of lowest performers and the moderate performers report that it is very important for them to do well in mathematics and in test language subjects, but the equivalent percentages for science was just over 20%, on average across the OECD countries. Countries with the largest proportions of top performers reporting that doing well in science is very important to them include Portugal (79%), Spain (70%), Greece (65%),[2] Iceland (63%), France (61%), the United States (61%) and Canada (60%) (Table A3.7).

An implication of this evidence is that the pool of talent for future science workers may be increased by seeking to raise strong performers' motivation to learn science – that is, concentrating on those just below top performers. It may be particularly productive to show students that learning science is useful for further study and that opportunities exist for rewarding careers in science.

Are top performers confident learners?

PISA has shown that confidence is strongly linked with performance at the student level. The evidence presented below shows that top performers in science are very confident learners, more so than any other performance group.

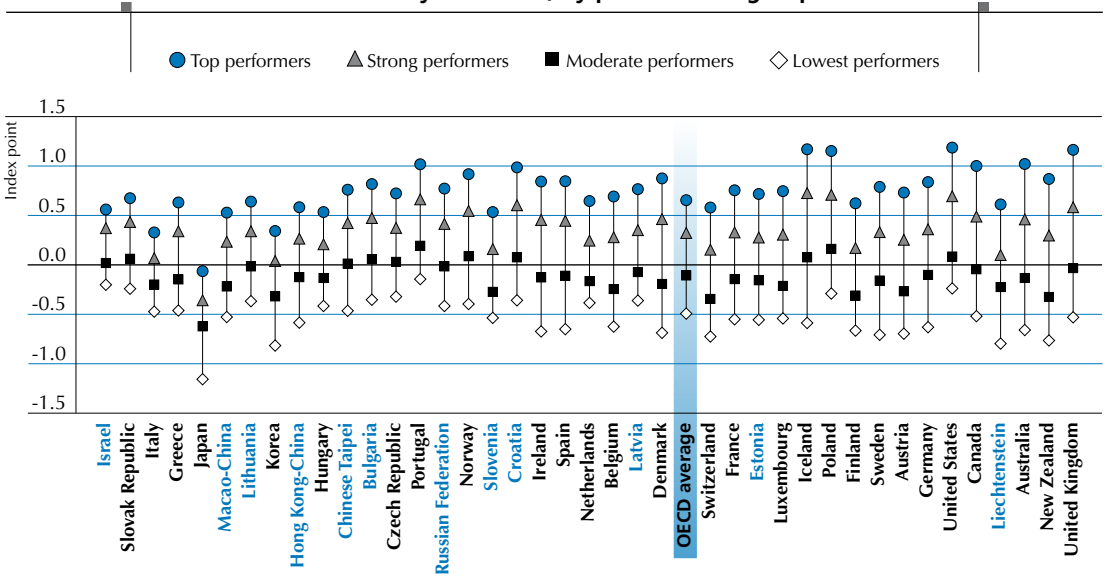
Self-efficacy in science

For these reasons, PISA 2006 included measures of how much students believe in their own ability to handle tasks effectively and overcome difficulties (the *index of self-efficacy in science*). Successful learners are not only confident of their abilities. They also believe that investment in learning can make a difference and help them to overcome difficulties. By contrast, students who lack confidence in their ability to learn what they judge to be important and to overcome difficulties may not find success, not only at school, but also in their adult lives.

Self-efficacy goes beyond how good students think they are in subjects such as science. It is more concerned with the kind of confidence that is needed for them to successfully master specific learning tasks, and is therefore not simply a reflection of a student's abilities and performance. The relationship between students' self-efficacy and students' performance may well be reciprocal; with students with higher academic ability being more confident and higher levels of confidence, in turn, improving students' academic ability. A strong sense of self-efficacy can affect students' willingness to take on challenging tasks and to persist in tackling them.

To assess self-efficacy in PISA 2006, students were asked to rate the ease with which they believe they could perform eight scientific tasks relating to such issues as earthquakes, health, labelling of food items, the effect of changes to the environment on the survival of certain species, garbage disposal, treatment of diseases, acid rain and life on Mars.

Figure 3.5
Self-efficacy in science, by performance group



Countries are ranked in ascending order of the difference in the mean index between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.8a.

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As in previous surveys (OECD, 2001 and 2004), in PISA 2006 self-efficacy was strongly related to student performance with an average increase of 38 score points for each one standard deviation increase in the index score.

Top performers in science demonstrated a much higher degree of self-efficacy than even strong performers (index values of 0.77 and 0.36, respectively), on average across the OECD countries. This difference was significant and it was also significant in all countries (Figure 3.5 and Table A3.8a).

Self-concept in science

Students' academic self-concept is both an important outcome of education and a trait that correlates strongly with student success. Belief in one's own abilities is extremely relevant to successful learning. Self-concept in science the general level of belief that students have in their academic abilities as opposed to self-efficacy which measures students' level of confidence in tackling specific scientific tasks.

On average, across OECD countries, 65% of students in PISA 2006 reported that they could usually give good answers in science tests, but only 47% reported that science topics were easy for them. Student self-concept was strongly associated with performance – there was a 27 score point difference associated with a change of one standard deviation on the self-concept index (OECD, 2007).

Table 3.3 shows the average percentages of students in each performance groups agreeing or strongly agreeing with self-concept in science statements. Top performers reported strong self-concept in science with at least 80% of top performers on average across the OECD countries reporting that they can usually give good answers to test questions on science topics, that they understand very well the science concepts they are taught and that they learn science topics quickly. In all OECD countries, top performers reported significantly stronger self-concept in science than strong performers (Table A3.9a). An illustration of this is that while 70% of the top performers reported that science topics are easy for them, this was the case for only 55% of strong performers, on average across the OECD countries (Table 3.3).

In summary, the PISA 2006 results indicate that there is a significant difference between top performers and strong performers regarding their perception of themselves as science learners. Strong performers are comparatively less confident, both in terms of their confidence to tackle science tasks and their assessment of their own abilities in science lessons. While it is difficult to determine the direction of the relationship between confidence and good performance – that is, whether students report being more confident as science learners because they obtain higher marks in science or whether the reverse is true – PISA results show that top performers on average are very confident science learners. To what extent could strong performers improve their performance if they had increased confidence in their abilities to tackle science? Further research is required to shed light on this complex relationship.

Table 3.3
Self-concept in science

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with the following:

Self-concept in science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I can usually give good answers to test questions on science topics.	49	60	76	87
When I am being taught science, I can understand the concepts very well.	44	53	69	82
I learn science topics quickly.	41	50	66	80
I can easily understand new ideas in science.	42	49	65	79
Science topics are easy for me.	36	40	55	70
Learning advanced science topics would be easy for me.	42	39	52	68

ARE TOP PERFORMERS INTERESTED IN CONTINUING WITH SCIENCE?

Despite their young age, it is informative to examine the extent to which top performers in science report that science is of value to them, that they are confident in tackling various science tasks and the extent to which they aspire to use science in the future, either through further studies or in their future careers. Equally informative are their reports on how well they feel that school has prepared them for future science careers, and indeed, how well informed they feel about potential science-related careers. All of these measures can shed light on how many 15-year-olds are well placed to continue with science in terms of their abilities, their aspirations and their access to information on how to achieve their goals.

Do top performers perceive science to be of value?

The PISA 2006 results paint an encouraging picture of young people's value of science in general (OECD, 2007). However, students' reports also indicate that they do not necessarily relate science to their own lives or behaviour. For example, while 87% of students in the OECD on average report that science is important to society, only 57% report that science is very relevant to them.

Table 3.4 shows the average percentages of agreement for each performance group on statements about two PISA measures: on *general value of science* and *personal value of science*. Index values were calculated using students' levels of agreement with each of the 10 statements. On average across the OECD countries, at least 80% of top performers reported agreement with 7 out of the 10 statements relating to the value of science. Of particular note, in relation to the personal value of science, 80% of top performers reported that they will use science in many ways as an adult and 76% reported that science is very relevant to them and that there will be many opportunities to use science when they leave school. These percentages are substantially higher than for the other performance groups, notably lowest performers, but there are significant differences even between top performers and strong performers in nearly all the OECD countries (Tables A3.10a and b and A3.11a and b).

Table 3.4
General and personal value of science

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with each statement:				
General value of science	**Lowest performers**	**Moderate performers**	**Strong performers**	**Top performers**
	%	%	%	%
Science is important for helping us to understand the natural world.	85	93	96	97
Advances in science and technology usually improve people's living conditions.	80	92	96	96
Science is valuable to society.	75	86	92	95
Advances in science and technology usually help improve the economy.	68	79	86	89
Advances in science and technology usually bring social benefits.	63	74	79	81

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with each statement:				
Personal value of science	**Lowest performers**	**Moderate performers**	**Strong performers**	**Top performers**
	%	%	%	%
I find that science helps me to understand the things around me.	63	71	82	89
I will use science in many ways when I am an adult.	53	59	70	80
Science is very relevant to me.	46	51	64	76
When I leave school there will be many opportunities for me to use science.	49	54	65	76
Some concepts in science help me see how I relate to other people.	61	59	58	60

Do top performers intend to pursue science?

One aspect of a good science education is to draw talented students into a future commitment to the field so that as adults they will contribute to the scientific progress and productivity of their societies. PISA 2006 sought to ascertain students' aspirations with regard to study beyond secondary school and active involvement in scientific careers or projects.

Top performers in science often aspire to a science career. Figure 3.6 shows results for students in each performance group on *the index of future-oriented science motivation*. Index values were calculated using students' levels of agreement with each of four statements. These statements are displayed in Table 3.5 with the average percentages of students agreeing or strongly agreeing with them. On average across the OECD countries, 61% of top performers reported that they would like to work in a career involving science and 56% reported that they would like to study science after secondary school. In contrast, top performers showed less enthusiasm for working on science projects as an adult or spend their life doing advanced science (47% and 39% on average across the OECD countries, respectively).

Table 3.5
Motivation to use science in the future

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with each statement:

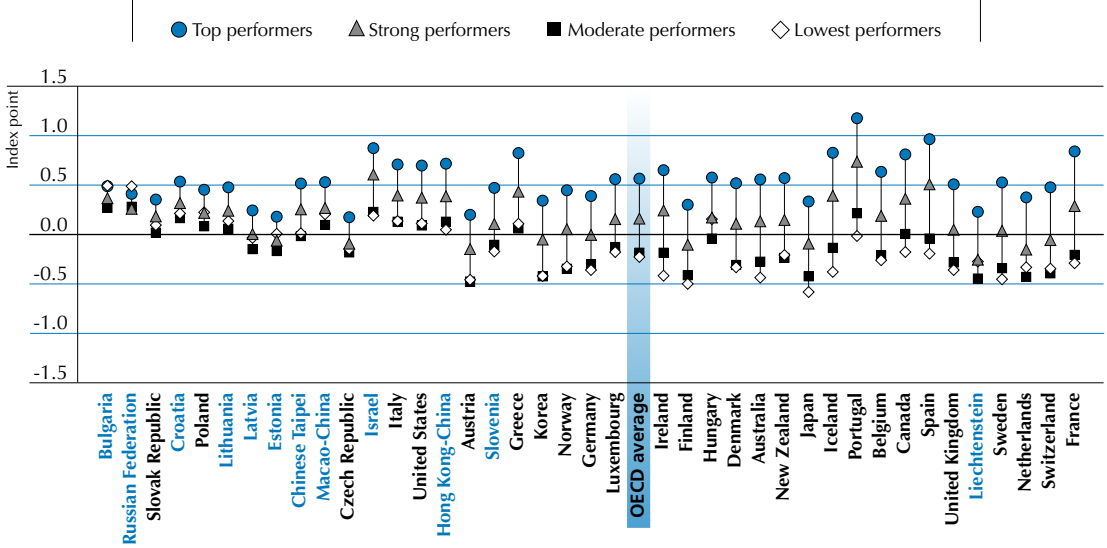
Future-oriented science motivation	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
I would like to work in a career involving science.	27	30	45	61
I would like to study science after secondary school.	21	23	39	56
I would like to spend my life doing advanced science.	17	15	24	39
I would like to work on science projects as an adult.	20	19	31	47

Whether the desire to pursue science is driving the performance of top performers or not is difficult to ascertain. However, as Figure 3.6 shows, the level of aspiration to engage in future scientific activities and involvement by students was positively related to students' science performance. Among the OECD countries the difference in the index of future-orientation towards science between top performers and the lowest performers was more than three quarters of a standard deviation. Only 27% of the lowest performers reported that they would like to work in a career involving science, across the OECD countries on average. Particularly instructive is the fact that the gap between top performers and the strong performers among the OECD countries is 40% of a standard deviation, a substantively large difference between the two adjacent performance groups. For example, on average across the OECD countries only 39% of the strong performers reported that they would like to study science after secondary school – this compares to 56% of top performers. These differences in the index value between top performers and strong performers are observed in all OECD countries except the Slovak Republic, most in the order of 22% to 54% of a standard deviation (Table A3.12a).

The evidence presented above suggests that those countries that are able to increase the proportion of top performing students in science are enlarging the pool of students who have stronger aspirations for future science study and activity. If this indicator is predictive of actual study and career choice, it can be expected to translate into more adults who are prepared for and desire to enter scientifically-oriented occupations.

In the past, females have been much less likely to choose scientific study and science careers than males. It is therefore instructive to compare future-oriented science aspirations according to gender. Table A3.12b shows future-oriented science aspirations by gender.

Figure 3.6
Future-oriented motivation to learn science, by performance group



Countries are ranked in ascending order of the difference in the mean index between top and strong performers.
Source: *OECD PISA 2006 Database,* Table A3.12a.

In general, females indicate lower aspirations than males to engage in future scientific activities. For example, among top performers males have an index value of 0.61 on the aspirations scale in contrast to the female index value of 0.47 on average across the OECD countries. The difference between genders is statistically significant. Of the 28 OECD countries included in this comparison, 12 showed that male top performers in science had significantly higher aspirations to use science in the future than females. Only in the Czech Republic and Poland did female top performers report higher aspirations to use science in the future than male top performers (Table A3.12b).

Yet, the overall aspiration pattern among science top and strong performers is the same for both males and females. As is the case for males, female top performers report higher aspirations to use science in the future than female strong performers. So, the goal of increasing the numbers of adults engaged in the study and pursuit of scientific activities by fostering aspirations is valid for both males and females.

Do top performers feel prepared for science-related careers?

Career preparation

In PISA 2006 students were asked a series of questions about how well the school has prepared them for future science-related careers. *The index of school preparation for science-related careers* was derived from students' level of agreement with the following statements: *i)* the subjects available at my school provide students with the basic skills and knowledge for a science-related career; *ii)* the science subjects at my school provide students with the basic skills and knowledge for many different careers; *iii)* the subjects I study provide me with the basic skills and knowledge for a science-related career; and *iv)* my teachers equip me with the basic skills and knowledge I need for a science-related career. A four-point scale with the response categories "strongly agree", "agree", "disagree" and "strongly disagree" was used.

Top performers in science report being significantly better prepared for science-related careers than students in other performance groups, even the strong performers (index values of 0.31 for top performers and 0.10 for strong performers, on average across the OECD countries [Table A3.13a]). It is worth noting that the majority of students in all performance groups reported that their schools are preparing them well for science-related careers. However, the percentages of top performers agreeing with each statement were larger than those for all the other performance groups. On average across the OECD countries, at least 80% of top performers agreed that school has prepared them for science-related careers (Table 3.6). Indeed, at least three-quaters of students in each performance group reported agreement with the statements about their schools in general. There are notable differences, however, between top performers and the lowest performers with regard to statements aimed at the students' individual preparation, as distinct from the school in general: on average across the OECD countries, top performers agreed that the subjects they study (82%) and their teachers (81%) provide them with the basic skills and knowledge for a science-related career (compared to 65% and 67% respectively of low performers).

Table 3.6
Science-related careers: school preparation and student information

Average percentage of students by performance group in OECD countries agreeing or strongly agreeing with each statement:

General value of science	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
The subjects available at my school provide students with the basic skills and knowledge for a science-related career.	78	82	85	88
The science subjects at my school provide students with the basic skills and knowledge for many different careers.	75	79	83	85
The subjects I study provide me with the basic skills and knowledge for a science-related career.	65	69	75	82
My teachers equip me with the basic skills and knowledge I need for a science-related career.	67	71	76	81

Average percentage of students by performance group in OECD countries reporting that they are very well informed or fairly informed about the following:

Student information on science-related careers	Lowest performers %	Moderate performers %	Strong performers %	Top performers %
Where to find information about science-related careers.	49	52	56	59
The steps a student needs to take if they want a science-related career.	50	50	53	58
Science-related careers that are available in the job market.	47	45	50	55
Employers or companies that hire people to work in science-related careers.	43	36	34	34

Information on science-related careers

Top performers in science report that their schools have prepared them well for science-related careers, but how well informed do they report being about possible science-related careers? The *index of student information on science-related careers* was derived from students' beliefs about their level of information about the following topics: *i)* science-related careers that are available in the job market; *ii)* where to find information on science-related careers; *iii)* the steps students need to take if they want a science-related career; and *iv)* employers or companies that hire people to work in science-related careers. A four-point scale with the response categories "very well informed", "fairly informed", "not well informed" and "not informed at all" was used.

Table 3.6 reveals that significant proportions of top performers do not feel well informed about science-related careers. While at least 80% reported that their schools had prepared them well for science-related careers, only between 55 and 59% of top performers on average across the OECD felt informed about where to find information, about the steps they would need to take and about available jobs. Only 34% of top performers reported being informed about employers or companies that hire people to work in science-related careers – a lower percentage than that for lowest performers (43%) on average across the OECD countries (Table 3.6).

In short, top performers perceived themselves to be well prepared by their schools for a science-related career, but less well informed about the careers available. There is not much variation among the performance groups with regard to information on science-related careers (Table A3.14a). It is particularly striking, however, that only 56% of strong performers and 59% of top performers report being informed on where to find information about science-related careers. This is an area where schools can act.

When top performers are relatively unmotivated, what are they like?

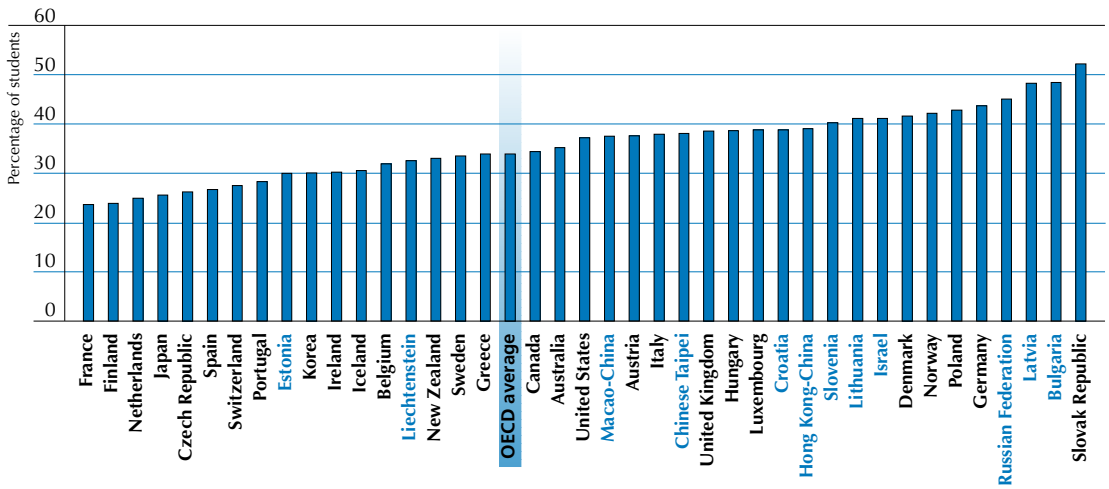
The previous section shows that top performers in science tend to have high aspirations for science study beyond secondary school and for active involvement in scientific careers or projects in future (Table A3.12a). This finding is encouraging as top performers at the age of 15 constitute a potential pool for future scientifically-oriented occupations. But are all top performers in science motivated towards continuing with science? The last section of this chapter studies relatively unmotivated top performers in science than others; including whether the proportion of these students varies across countries; and who they are.

Relatively unmotivated top performers in science are defined as top performers in science who reported motivation levels below the average motivation of science strong performers in the *index of future-oriented science motivation*. From a policy perspective, this comparison between strong and top performers seems relevant as it highlights differences between those who excel and those that are closest to excellence.

Figure 3.7a

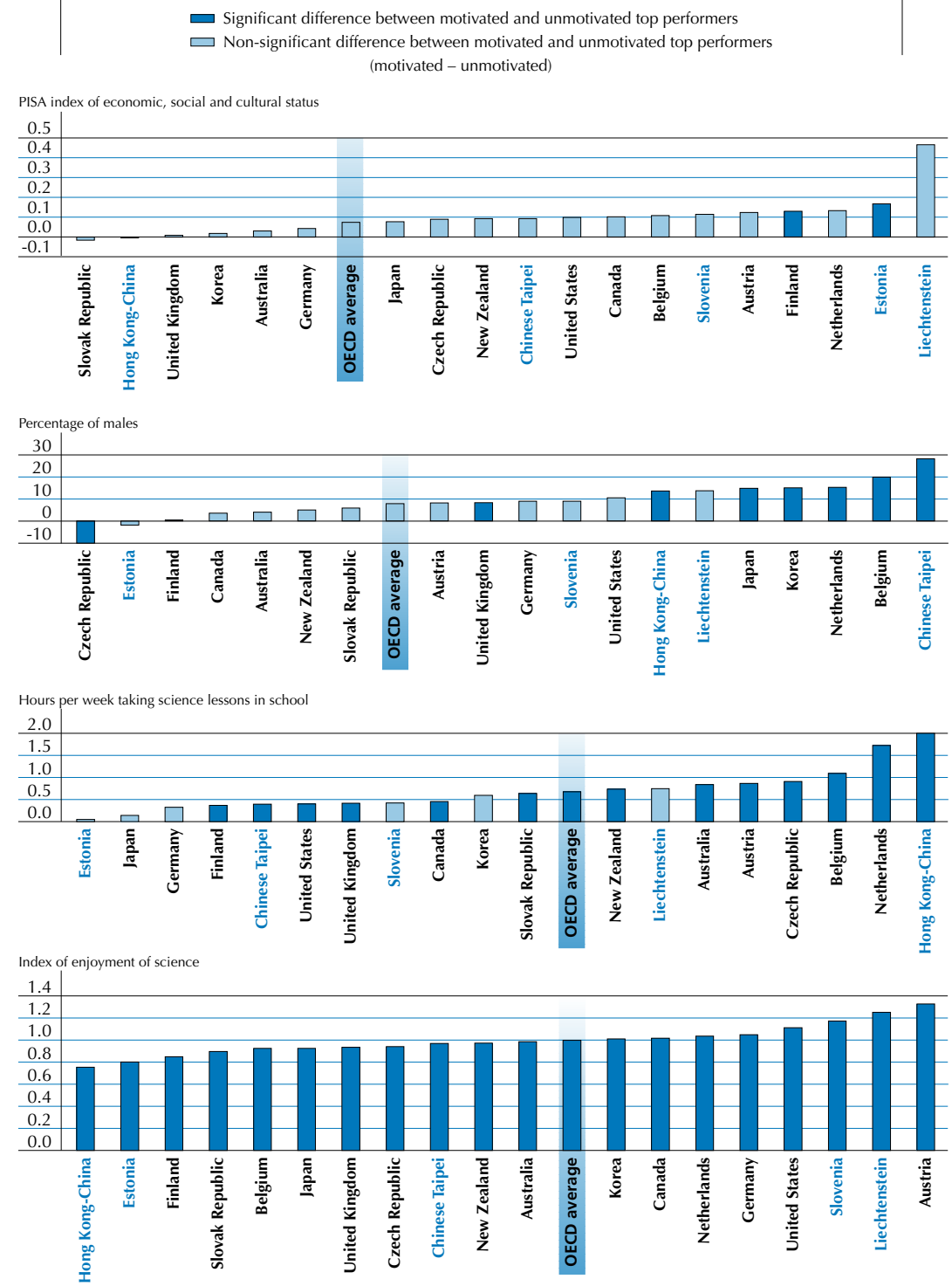
Proportion of relatively unmotivated top performers, by country

Percentage of top performers in science who reported motivation levels below the average motivation of science strong performers in the index of future-oriented science motivation



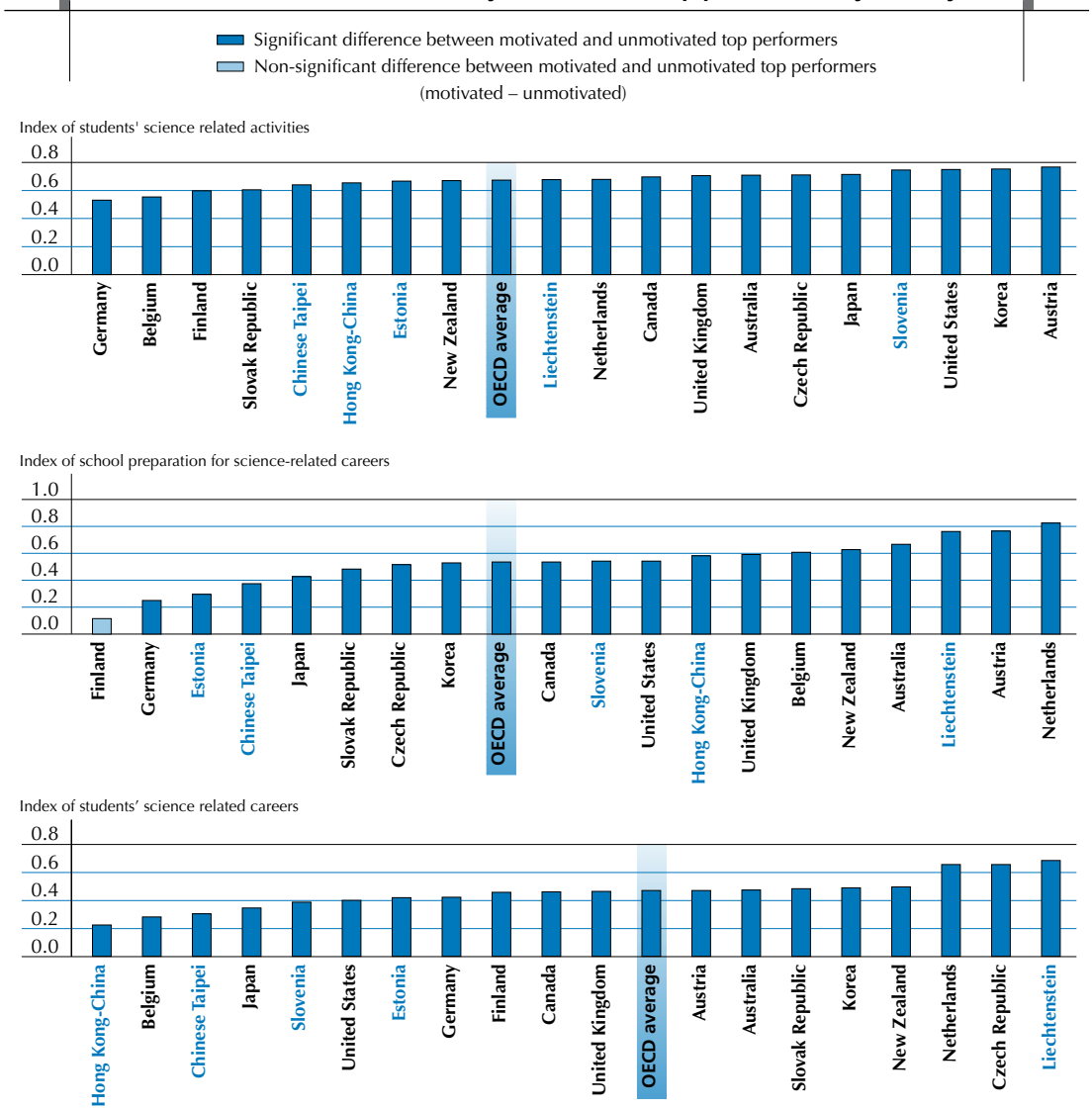
Countries are ranked in ascending order of the percentage of relatively unmotivated top performers.
Source: *OECD PISA 2006 Database,* Table A3.15.

Figure 3.7b [1/2]
Some characteristics of relatively unmotivated top performers, by country



For each chart included in the Figure 3.7b, countries are ranked in ascending order of the characteristic described in the chart.
Source: *OECD PISA 2006 Database,* Table A3.15.

Figure 3.7b [2/2]
Some characteristics of relatively unmotivated top performers, by country



For each chart included in the Figure 3.7b, countries are ranked in ascending order of the characteristic described in the chart.
Source: *OECD PISA 2006 Database,* Table A3.15.

Across OECD countries, 34% of top performers reported lower future-oriented motivation than the average strong performer (Table A3.15). However, this varies significantly across countries. In the Slovak Republic, Latvia and Bulgaria about half of top performers report being less motivated than the average national strong performer. At the other extreme, in France, Finland, and the Netherlands less than a quarter of top performers in science report to have below the average *index of future-oriented science motivation* than science strong performers in the country.

Given the large proportions of relatively unmotivated students among top performers in science in some countries, understanding who these students are and what characterises may result in important insights for educational policy makers. What characterises these less motivated top performers? Do they come from a disadvantaged background? Are male students more or less likely to be relatively unmotivated top performers? Do they experience teaching and learning differently? Do they engage similarly in science-related activities? And do the report having access to the same level of information?

Relatively unmotivated top performers are not necessarily socio-economically disadvantaged compared with the motivated top performers. The average socio-economic background for the less motivated top performers does not differ from the average socio-economic background for the motivated top performers in all 19 countries where sufficient data are available except Austria and Greece.

Gender also plays little or no role in explaining differences in motivation among top performers in science. In 11 countries, no gender difference is observed between the motivated and relatively unmotivated top performers. Females however are more likely than males to be relatively unmotivated top performers in Belgium, the Netherlands, Korea, Japan and the United Kingdom as well as the partner economies Chinese Taipei and Hong Kong-China. Only in the Czech Republic are male top performers more likely than females to be relatively unmotivated.

Greater difference between the motivated and less motivated top performers is observed in students' experience in learning science. The motivated top performers spend longer time in science lessons in school in 13 countries. Motivated top performers spend at least one hour longer in science lessons than the less motivated top performers in the Netherland, Belgium and the partner economy Hong Kong-China. Again, the data do not allow to infer what is cause and effect here, at least one explanation is that motivate top performers spend more time in science because of their motivation.

Even more significant is the difference found in enjoyment of science learning. In all 19 countries where the data are available, motivated top performers in science enjoy learning science more than relatively unmotivated top performers in science: they generally report having fun when they are learning science topics, they like reading about science, they are happy doing science problems, they enjoy acquiring new knowledge in science and they are interested in learning about science. The difference between the motivated and less motivated top performers is at least three-quarters of a standard deviation in the index of enjoyment of science, and the difference is one standard deviation or more in some countries including Austria, the United States, Germany, the Netherlands, Canada, Korea and the partner countries Liechtenstein and Slovenia.

In their daily life, motivated top performers in science tend to engage significantly more than relatively unmotivated top performers in science in science related activities. Motivated top performers engage in the followings activities more frequently than relatively unmotivated top performers in science: Watch TV programmes about science, borrow or buy books on science topics, visit web sites about science topics, listen to radio programmes about advances in science, read science magazines or science articles in newspapers and attend science club. The difference between in the i*ndex of students' science-related activities* between motivated and less motivated top performers ranges from half a standard deviation to three-quarters of a standard deviation.

In terms of the information provided by their schools, motivated top performance in science report more often than relatively unmotivated ones receiving enough information, basic skills and knowledge for a future career in science. The differences in the *index of student information on science-related careers* among motivated and relatively unmotivated top performers range from around a quarter of a standard

deviation in Belgium and partner economy Hong Kong-China, to two thirds or more of a standard deviation in the Netherlands and in partner countries Lichtenstein and the Czech Republic.

All in all, differences in motivation among top performers in science appear to be driven by student experiences with teaching and learning, their engagement in science activities, and the information they receive about future science related careers. Coupled with the limited role of socio-economic background and gender in explaining these differences, these findings provide educational policy makers food-for-thought in the design of policies to promote motivation among all students and in particular among top performers in science.

IMPLICATIONS FOR EDUCATIONAL POLICY AND PRACTICE

The main finding of this chapter is that top performing students are dedicated and engaged learners. They tend to devote more time to studying than other students, above all at school. When not at school, they engage in science related activities relatively often. Last but not least, they regard learning science as a potential career investment.

In terms of their experiences, attitudes, motivations and aspirations, top performers in science are dedicated and engaged learners who aspire to a career in science. Top performers in science also tend to spend more time in regular science lessons at school and more frequently engage in science related activities. They are confident learners interested in a broad range of science topics, they enjoy learning science even when the content is challenging and they believe they are good at science. They think that learning science will prove useful for them in their further studies and professional activities and more often aspire to a career in science, whether this is a cause or consequence of their performance and engagement with science. However, top performers often do not feel well informed about potential career opportunities in science, which is an area school policy and practice can act upon. The link between attitudes and motivations is strengthened by evidence suggesting that motivation among top performers is unrelated to socio-economic factors but rather a reflection of their enjoyment and active engagement in science learning inside and outside school.

At the same time, in a number of countries there are significant proportions of top performers who show comparatively low levels of interest in science. While these education systems have succeeded in conveying scientific knowledge and competencies to students, they have been less successful in engaging them in science-related issues and fostering their career aspirations in science. These countries may thus not fully realise the potential of these students. Fostering interest and motivation in science, factors that this report shows to be highly related to engagement with science, thus seems an important policy goal in its own right. Efforts to this end may relate to improved instructional techniques and a more engaging learning environment at school but they can also extend to students' lives outside school, such as through establishing and making available more and better content on the Internet or in video games that applies scientific principles; establishing contests on the Internet with prizes for students who achieve particular levels of performance or stages of accomplishment; more and better television programming using children's cartoons to enlist interests in science and scientific curiosity for younger children; or science fiction novels and series of books on adventures or mysteries based upon scientific and technical knowledge, ingenuity and solutions with characters.

In sum, educational excellence goes hand in hand with promoting student engagement in and enjoyment of science learning both inside and outside the school. The payoff is quite significant: a large and diverse talent pool ready to take up the challenge of a career in science. In today's global economy, it is the opportunity to compete on innovation and technology.

Notes

1. These countries were Denmark, Germany, Iceland, Italy, Korea, Luxembourg, New Zealand, Poland, Portugal and Turkey, and the partner countries and economies Bulgaria, Colombia, Croatia, Hong Kong-China, Macao-China and Qatar. In examining the results from the PISA parent questionnaire, it should be noted that in some countries non-response was considerable. Countries with considerable missing data in the parent questionnaire area listed in the following together with the proportion of missing data in brackets: Portugal (11%), Italy (14%), Germany (20%), Luxembourg (24%), New Zealand (32%), Iceland (36%) and Qatar (40%).

2. Note however that for both Portugal and Greece we are talking about a small proportion of all students as only 3% of all students are top performers. The evidence in this case for these two countries should be interpreted with caution.

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