

Science and Maths Education in Ireland: Provision, Participation and Achievement

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Editorial

With the annual publication of the Leaving Certificate results, some commentators in industry and education have expressed concern over the standards attained in science and maths. The main problem cited is the low number of students studying maths and science at a higher level in second and third level education.

Concerns exist that relatively low student numbers in these subject areas will have a detrimental impact on efforts to attract research and development (R&D) and build a knowledge economy. Indeed, the strategy document *Building Ireland's Smart Economy: A Framework for Sustainable Economic Renewal (2008)* recognises that science-based technology forms one of the cornerstones of the economy and that utilising the knowledge, skills and creativity of people is central to developing innovation and ideas.

This *Spotlight* examines science and maths education in Ireland. In particular, it assesses the provision, participation and achievement in maths and science at second and third level, and examines how Ireland compares to other countries in this regard. The *Spotlight* also explores the reasons why the uptake of these subjects is relatively low. Finally, with a view to looking forward, the *Spotlight* outlines expert recommendations and initiatives for encouraging participation in maths and science education.

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Executive Summary

This *Spotlight* examines provision, participation and achievement in maths and science education in Ireland, and reflects on the experience of other countries in this regard. The main findings are as follows:

Provision

- In Irish schools, science is not a compulsory subject at any stage of education. Maths is only mandatory for the Junior Certificate and the Leaving Certificate Applied.
- Ireland is in a unique position among 21 other European regions in not having science a compulsory subject at lower-secondary level.
- Students in Irish schools receive a lower proportion of teaching time in science compared to the OECD and EU (19) average. For maths, the proportion of teaching time is similar to the OECD and EU (19) average.

Participation

- Participation levels in Irish schools in maths examinations are high at both the Junior and Leaving Certificate levels. Participation levels in science in the Junior Certificate exam are also relatively high but fall for the Leaving Certificate exam.
- The numbers taking higher level maths are a relatively small proportion of students in this subject. This is particularly true for the Leaving Certificate exam.
- While the numbers of science students taking the high level papers in the Leaving Certificate are relatively high compared to maths, there are low levels of participation in physics and chemistry. International research, however, shows that these trends in maths and science are also evident in many other countries.
- From looking at CAO entry requirements, some commentators maintain that the high achievers are not selecting to study general science, engineering and technology courses. At the same time, comparative data shows that Ireland performs relatively well in

terms of the proportion of undergraduate and postgraduate students who are awarded with science, engineering and technology degrees. In 2007, Ireland was ranked 3rd highest out of 29 OECD countries.

Achievement

- Over the last three years, achievement levels in maths and science at the Junior and Leaving Certificate have remained broadly constant.
- In terms of comparative International assessments, Ireland's score in science was higher than the OECD average and similar to the OECD average for maths. Analysis shows that while lower achievers in maths and science in Ireland do well compared to other countries, there is room for improvement among the higher achievers.

A way forward?

- A review of international best practice and expert recommendations has identified ways to increase participation levels in higher level examinations in maths and science. These include enhancing the skills of teachers, changing teaching methods, giving maths and science greater emphasis in the curriculum, and incentivising students to take up these subjects at second and third level.
- In particular, enhancing the skills and capacity of teachers is a key driver for enhancing performance. Some commentators argue that if high achievers in maths and science remain in education, this will create a virtuous circle in which high quality teachers will be able to provide enthusiasm and greater understanding to students who, in turn, will become high achievers with some also entering the teaching profession.
- At present, changes in the maths and science curriculum are being tested by the Department of Education and Science. Some of these changes involve enhancing teacher professional development and emphasising a problem solving approach to teaching.

Provision, Participation and Achievement in Maths and Science Education in Ireland

Maths and science at second level education

At second level, the education system is divided into two cycles, the junior cycle and the senior cycle. Participation and achievement in the junior cycle is assessed first before the position in the senior cycle is examined.

The junior cycle

The junior cycle falls within the compulsory period of education¹ with almost all students undertaking courses leading to the Junior Certificate. There are two programmes of study for the Junior Certificate, the mainstream programme and the Junior Certificate School Programme.² Students at risk of leaving school early may follow the Junior Certificate School Programme.

When examining the number of students who undertake the Junior Certificate examinations, analysis of CSO data shows that some differences in the levels of participation in maths and science can be identified.

In recent years, around 57,000³ students undertake the Junior Certificate examinations annually. About 96% of the students take a maths paper, reflecting strong levels of participation in this subject, but a lower proportion, 87%, take a science paper.

In the Junior Certificate, all students must study maths. Science is not a compulsory subject despite it being a requirement for the Junior Certificate School Programme. This means that although science must be taught in every school, students can choose whether they wish to study the subject.

However, despite the higher overall participation levels in maths at Junior Certificate, fewer

¹ http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Junior_Cycle

² <http://jcsp.slss.ie>

³ 57,287 students sat the Junior Certificate in 2008, 56,031 in 2007 (excluding VTOS candidates) and 56,471 in 2006 (excluding VTOS candidates) http://www.education.ie/servlet/blobServlet/statistics_key_06_07.pdf

students select to undertake the higher level examination than is the case for science, as detailed in Table 1.

Table 1: Participation in Junior Certificate maths and science, 2006-2008

Year	No of students participating in the subject	Higher level	Ordinary level	Foundation level
Maths				
2008	55,158	23,634 (42.8%)	26,384 (47.8%)	5,140 (9.3%)
2007	56,512	23,804 (42%)	27,094 (47.9%)	5,614 (9.9%)
2006	56,939	24,205 (42.5%)	26,820 (47%)	5,914 (10.3%)
Science				
2008	48,950	33,754 (68.9%)	15,125 (30.8%)	71 (0.1%)
2007	50,106	35,112 (70%)	14,892 (29.7%)	102 (0.2%)
2006	50,091	33,672 (67.2%)	14,695 (29.3%)	1,724 (3.4%)

Source: CSO

The table clearly shows that from 2006-2008, more science students, over two thirds (67.2%-70%), engaged in the higher level examination with less than half (42%-42.8%) of the maths students undertaking the higher level paper in the junior cycle. This data clearly evidences a bias against higher level maths among students at Junior Certificate level.

When examining standards in maths and science education, it is useful to assess achievement levels (see Appendix A, Table A.1, for details of the examination results from 2006-2008 for Junior Certificate maths).

Data shows that from 2006-2008, a degree of consistency exists in the achievement of Junior Certificate maths subjects within each of the levels of papers (higher, ordinary and foundation). For example, in the higher level paper for the three years covered, the percentage of students achieving A grades ranged from 17-18%, B grades from 30-32% and C grades 28-32%.

Some differences, however, can be identified between the papers with a lower proportion of

students taking the foundation level paper achieving A grades.

In regard to Junior Certificate science, a similar pattern emerges with limited differences evident between levels rather than the year of study (see Appendix A, Table A.2)

Data shows that in the higher level paper, the percentage of students achieving A grades for the three years covered ranged from 8-10%, B grades from 30-32% and C grades 37-41%. By contrast, the percentage of students achieving A grades in the ordinary level paper (2006-2008) is much lower ranging from 1-3%.

The senior cycle

The senior cycle is comprised of four elements as follows:

- Transition Year (optional).
- Established Leaving Certificate.
- Leaving Certificate Applied.
- Leaving Certificate Vocational Programme.

In a similar pattern to the Junior Certificate, data shows that there are greater participation levels of students studying maths for Leaving Certificate compared to science. Every year, for instance, approximately 94% of students who study the Leaving Certificate take a maths paper while about 77% take a science paper.⁴ Therefore, while participation levels of maths students in the Leaving Certificate exam have remained high in the transition from the junior cycle, there is a fall of around 10% in the number of science students.

While neither maths nor science is compulsory in the Established Leaving Certificate,⁵ there is a compulsory maths subject called Mathematical Applications in the Leaving Certificate Applied.

In addition, as many schools, if not most schools, do require all pupils to undertake maths for the Leaving Certificate, this may explain the relatively high participation levels for this

⁴ State Examinations Commission (2009)

⁵ Irish is the only compulsory subject in the Established Leaving Certificate (it is compulsory except where exemptions apply).

subject. By contrast, not every school offers all of the Leaving Certificate science subjects.⁶

The following table (Table 2) details the participation levels of maths and science students from 2006-2008 in accordance with the level of paper taken. Again, the data mirrors the participation levels in the Junior Certificate with more students studying maths than science, but a greater number of students selecting to study higher level science than higher level maths.

Table 2: Participation in Leaving Certificate maths and science

Year	No of students	Higher level	Ordinary level	Foundation level
Maths				
2008	51,516	9,798 (19%)	35,915 (69.7%)	5,813 (11.2%)
2007	50,349	9,610 (19%)	35,160 (69.8%)	5,579 (11%)
2006	50,559	10,264 (20.3%)	35,191 (69.6%)	5,104 (10%)
Science				
2008	41,432	29,609 (71.5%)	11,823 (28.5%)	N/A
2007	43,769	32,129 (73.4%)	11,640 (26.6%)	N/A
2006	39,876	28,421 (71.2%)	11,455 (28.7%)	N/A

Source: CSO

Table 2 shows that from 2006-2008, almost three-quarters (71.2%-73.4%) of students studying Leaving Certificate science undertook a higher level paper while approximately one-fifth (19%-20.3%) of maths students chose to sit the higher level paper.

At the same time, however, the relatively high number of Leaving Certificate science students masks the low levels of participation in physics and chemistry. Data shows that the majority of Leaving Certificate science students chose to sit the biology exam, as detailed in Table 3 (overleaf).

⁶ In 2000 in Dáil Eireann, in response to a Parliamentary Question, the then Minister for Education and Science, Dr. Michael Woods, stated that based on 1999-2000 enrolments, the total number of schools providing the Leaving Certificate programme was 730. Of these, 162 did not provide physics, 202 did not provide chemistry, and 638 did not provide the combined subject of physics and chemistry. In percentage terms, this meant that 22% of schools did not provide physics, 28% did not provide chemistry, and 86% did not provide the combined subject physics and chemistry. <http://historical-debates.oireachtas.ie/D/0526/D.0526.200011210045.html>

Table 3 (below) shows that of all Leaving Certificate science students in 2008, 62.8% (18,322) undertook the biology exam, while 20.2% (5,904) sat chemistry and 16.9% (4,929) sat physics. This pattern is generally similar for the two preceding years 2007-2006.

Looking more broadly at the total number of students who sat the Leaving Certificate exam in 2008 (51,516), the proportions sitting chemistry and physics exams are much lower again at 11.5% and 9.6% respectively.

The Royal Irish Academy (2005) argues that the low uptake of these subjects at Leaving Certificate has a direct impact on the number of students opting for the physical sciences at third level and, therefore, on the future supply of engineers and scientists for the knowledge economy. Overall, they maintain that this development reduces the pool from which future employees will be drawn.

(higher, ordinary and foundation) (see Appendix A, Tables A.3 and A.4).

Summary of key findings at second level

- Science is not compulsory at Junior Certificate Level and not every school offers all of the Leaving Certificate science subjects.
- Participation in maths at second level education is strong (over 90%) but more students take higher level science than maths in both the Junior and Leaving Certificate.
- In Leaving Certificate, the majority of science students study biology (63%, 2008). Participation levels in physics (20%) and chemistry (17%) are relatively low.
- The low uptake of science subjects and higher level maths has a potential impact on the supply of engineers and scientists for the knowledge economy.
- Achievement levels in maths and science at Junior and Leaving Certificate level have remained broadly constant over the last number of years.

Data shows that in the Leaving Certificate maths higher level paper, for instance, the percentage of students achieving A grades (2006-2008) ranged from 14-16%, B grades from 31-35% and C grades 31-33%. Similar marginal differences in the range of grade results can also be identified in the higher and ordinary science subject papers.

Despite data showing Leaving Certificate results broadly remaining constant over the last three years, identifying those students who only achieved ABC grades in higher level papers serves to highlight the limited pool of school leavers who have progressed to a high standard.

Out of 51,121 students in 2008 who sat the Leaving Certificate maths exam, for example, 6,723 (16.5%) pupils achieved a C grade or more in the higher level paper.

Participation in maths and science at third level education

Table 3: Numbers of Leaving Certificate students undertaking biology, chemistry and physics 2006-2008

Year	Total no. sitting Leaving Certificate exam	Total no. sitting a science paper	Proportion of science students who took biology	Proportion of science students who took chemistry	Proportion of science students who took physics
2008	51,516	29,155 (56.6%)	18,322 (62.8%)	5,904 (20.2%)	4,929 (17%)
2007	50,349	28,476 (56.6%)	17,523 (61.6%)	5,730 (20.1%)	5,223 (18.3%)
2006	50,559	27,963 (55.3%)	17,048 (61%)	5,714 (20.4%)	5,201 (18.6%)

Source: CSO

In relation to the achievement levels for Leaving Certificate maths and science, a review of examination results from 2006-2008 demonstrates a general level of consistency over this three year period within each level

At third level, the proportion of applications for science and applied science degree courses (a category which includes maths), over the last five years, has generally remained constant between 12%-13.1%⁷ of all undergraduate courses.

While starting from a lower base, applications for science and applied science courses at diploma and certificate levels have grown steadily from 9.1% in

⁷ The data is, as indicated, from the CSO (Central Statistics Office). The data is presented in 17 separate groups. Although not stated, the figures for maths and science are aggregated into one group, Science and Applied Science.

2005 to 13.7% in 2008, as shown in the following table.

Table 4: Applicants to Science and Applied Science courses as a proportion of all undergraduates 2005-2009

	Applicants All Courses	Applicants Science and Applied Science	Science and Applied Science Applicants as a % of all Applicants
Third Level - Degree / Level 8			
2009	323,603	42,448	13.1%
2008	310,988	38,017	12.2%
2007	316,083	38,012	12%
2006	314,866	41,161	13%
2005	319,761	41,129	12.86%
Applicants to Third Level - Diploma /Cert Level 7/6			
2009	148,683	20,486	13.77%
2008	144,492	16,209	11.21%
2007	163,978	17,674	10.77%
2006	174,043	16,602	9.53%
2005	192,887	17,592	9.1%

Source: CSO

At postgraduate level, for the 2007/2008 academic year, the total number of new enrolments in Masters programmes in science and maths was 15.68% of the total number of new Masters students. In the same academic year, however, the proportion of new maths and science PhD candidates was much higher at 35.9% of the total number of PhD candidates.

Although the proportion of applications for third level science and applied science undergraduate degree courses have remained fairly constant, with the increase in university places over the last ten to twenty years, the Royal Irish Academy (2009) note that full-time undergraduate enrolments in science have actually increased from 7,900 in 1999 to 10,610 in 2007.

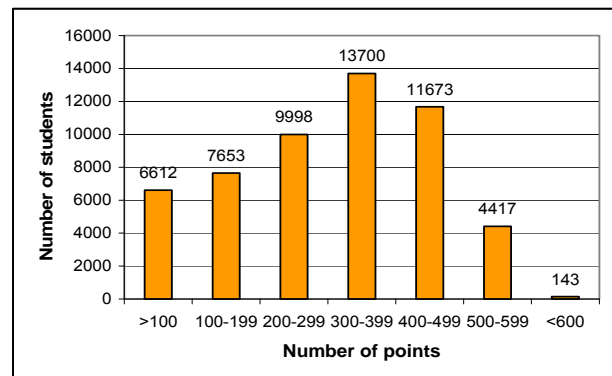
That being said, aggregate figures for applications and enrolments do not provide the complete picture. For instance, analysis conducted by the Expert Group in Future Skills Needs (EGFSN) (2008) has shown that the number of students entering honours degrees in computing and electronic engineering (areas of the economy in which the Group states that

skills gaps exist) has actually declined over the last number of years.⁸

An analysis of the CAO points system provides further insight into the level of participation in maths and science courses. As it is driven by demand and supply, the points system can provide an indication of the level of interest or competition for places on any particular course. This means that the more demand there is for any one college course (and the fewer the number of places available on the course), the higher the number of points will be required to secure successful entry.

The figure below shows the number of points scored by all students (54,196 students) who sat the Leaving Certificate in 2009.

Figure 1: Points attained in the Leaving Certificate, 2009



Source: Central Applications Office (2009)⁹

The figure shows that 300-399 points represents the single most common points scoring range. This points range was achieved by 25.3% (13,700) of all students in 2009 with 29.9% (16,223) achieving a points score of greater than 400 and 44.8% (24,263) achieving a score between 0-299 points.

In 2009, many of the general science, engineering and technology (SET) courses in Irish universities required points ranging from 325-360. For example, in round one of the CAO points and places race, the number of points required to study the following courses was:¹⁰

- Science at DCU – 350.

⁸ EGFSN (2008) *Future Requirements for High-level ICT Skills in the ICT Sector*.

http://www.egfsn.ie/publication/egfsnSearch.jsp?ft=/publications/2008/title_2513.en.php

⁹ <http://www.cao.ie/index.php?page=points&p=2009>

¹⁰ <http://www.cao.ie/>

- Applied physics at UL – 360.
- Science at NUIG – 325.
- Electronic or Electrical Engineering at UCD - 350.

This data clearly shows that in 2009, the top 30% of students in Ireland (those who achieved 400 points or more) exceeded the entry requirements for many of the general SET courses. By contrast, in 2009, many other vocational courses such as medicine, veterinary, pharmacy, accounting and primary education required much higher entry level points (CAO: 2009).¹¹

While the supply of places may also influence entry levels, overall, the number of entry points provides an indication of the relatively lower level of interest among students for studying general SET courses. Indeed, having conducted further research in this area, the Royal Irish Academy (2009) found that 60% of school-leavers who have undertaken higher-level mathematics in the Leaving Certificate do not take a science or engineering subject at third level.

The low level of interest among school-leavers in studying SET courses is further emphasised by a decline in the entry requirements for some university science courses. Selecting first-year science at UCD as a case study, the Royal Irish Academy (2008), for example, highlights that the minimum entry requirement has fallen from 420 points in 1998 to 300 points in 2006.

Relatively low level entry points for SET courses has a number of implications for the study of these subjects at third level. First, it is argued that low entry points can deter students who could and should undertake degrees in maths and science.¹²

¹¹ <http://www.cao.ie/index.php?page=points&p=2009> While many of these courses such as medicine and pharmacy require and involve the study of maths and science disciplines, this *Spotlight* examines the participation in general science, engineering and technology courses.

¹² See, for example, Royal Irish Academy (2009) *Making the Best of Third-level Science, Discussion Document*.

Summary of key findings at third level

- Applications for science and applied science undergraduate degree courses have remained constant (12-13%).
- Variations within the science discipline, however, can be identified. Full time undergraduate enrolments in science have increased but computer and electronic engineering courses have declined.
- Entry points for SET courses remain lower than vocational courses which attract the high achievers.
- As many students have not studied science to the required level, this is contributing to high drop out rates in some SET courses.

Second, the lower entry requirement is considered, at least in part, responsible for the reported high drop-out rates from SET courses at third level.¹³ Indeed, it has been reported that the average dropout / failure rate across all seven universities for science and technology courses in 2008 was 20%.¹⁴ This, according to many commentators (among them Royal Irish Academy, 2006 and EGFSN, 2008), is because students have not achieved in physics, chemistry and maths in the Leaving Certificate at the level necessary and are not adequately prepared to undertake courses of study in these fields.

It is also argued that the expansion in the number of third level students over the last ten to twenty years has exacerbated this problem as there is a cohort of school-leavers in university whose levels of preparation and attainment are less than those who entered college in the early 1990's (Royal Irish Academy, 2009).

How Ireland Compares?

In examining the relatively low participation levels in maths and science and reflecting on the experience of other countries, research shows that this is not a problem exclusive to Ireland (Childs, 2006).

<http://www.ria.ie/policy/pdfs/web%20version%20making%20the%20best%20of%20third%20level%20science.pdf>

¹³ http://historical-debates.oireachtas.ie/D/0497/D_0497_199812020064.html
<http://siliconrepublic.com/news/article/13664/randd/science-is-something-worth-talking-about-isnt-that-right-ted>
<http://www.irishtimes.com/newspaper/opinion/2009/0813/1224252497204.html?via=rel>

¹⁴ <http://siliconrepublic.com/news/article/13664/randd/science-is-something-worth-talking-about-isnt-that-right-ted>
 Choosing a Career in Science, *Irish Times*, 21st August, 2009
<http://www.irishtimes.com/newspaper/letters/2009/0821/1224253019354.html>

At present, for example, a similar debate on how to increase the uptake of maths and science is being held in the UK. In a major study, *Making Mathematics Count*, published in 2004, Smith (2004) highlighted that employers were facing difficulties in recruiting appropriately qualified scientists and engineers but also recognised that these subjects have a poor image and perception among some young people.

That being said, it is useful to examine how Ireland compares with other countries in relation to maths and science education. On the basis of relevant available data, this section provides comparative analysis in relation to three issues as follows:

- **Provision:** the time afforded to teaching maths and science and the provision of these subjects within the curriculum.
- **Participation:** the percentage of science graduates as a proportion of all graduates.
- **Achievement:** the standards achieved in comparative maths and science assessments.

Provision

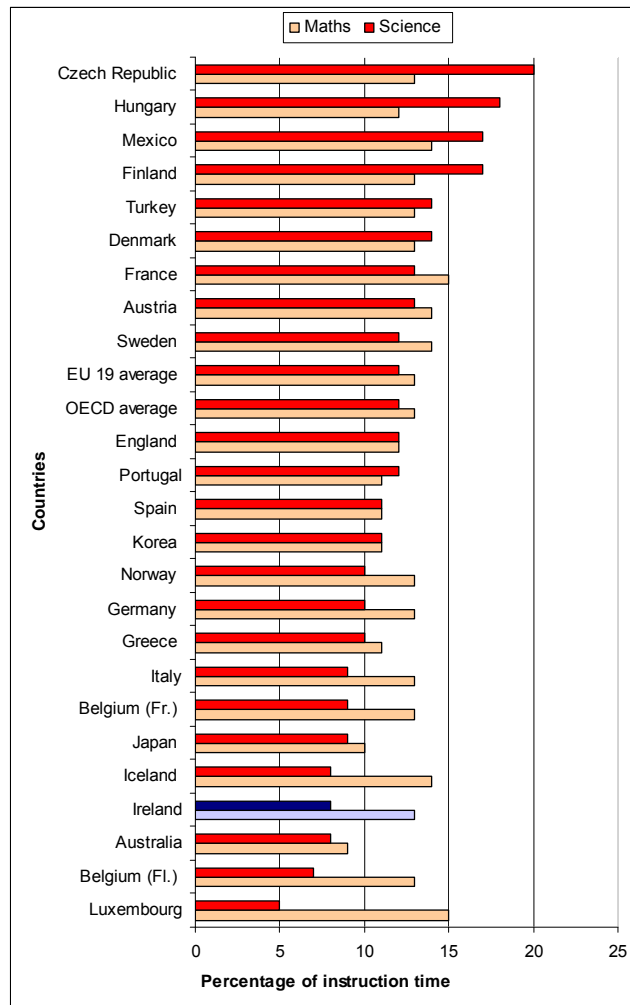
Data shows that compared to the OECD average and EU average,¹⁶ 12-14 year olds in Ireland receive a lower proportion of teaching time in science. As a percentage of the compulsory core curriculum, science in Ireland forms 8% of instruction time while the OECD and EU average is 12%.

Although being level with two other countries (Iceland and Australia), this figure places Ireland just in front of two other countries Luxembourg (5%) and Belgium (Fl)¹⁷ (7%), as shown in Figure 2.

Figure 2 also details the percentage of instruction time of the core curriculum allocated to maths for 12-14 year olds. This shows that maths in Ireland forms 13% of instruction time which is similar to the OECD and EU average. Six countries, out of 24, ranked above Ireland with France and Luxembourg allocating the highest percentage of instruction time, as a

proportion of the compulsory core curriculum, at 15%.

Figure 2: Instruction time for maths and science as a percentage of total compulsory instruction time for 12-14 year olds across different countries (2007)¹⁵



Source: OECD (2009)

Looking more closely at the provision of science in the school curriculum, research, conducted by West *et al* (1999) and the International Review of Curriculum and Assessment Frameworks (INCA)¹⁸, shows that Ireland is unique among 21 other European regions¹⁹ in not having science as a compulsory subject at lower-secondary level. At upper secondary level, science is less likely to be compulsory across the European regions. However, West *et al* (1999) shows that science at some stage and in

¹⁵ Countries are ranked in terms of the percentage of time given to science.

¹⁶ Nineteen EU countries are included in the average

¹⁷ Flanders

¹⁸ The International Review of Curriculum and Assessment Frameworks (INCA) www.inca.org.uk

¹⁹ 21 regions are made up of 18 countries, with Belgium as two regions and the UK as two regions 'England, Wales and Northern Ireland' and 'Scotland'.

some format is compulsory in 15 out of 21 European regions at upper-secondary level. Ireland, the UK, Spain, the Netherlands and Portugal stand out as the exceptions in that science is not compulsory at this level.

Participation

In terms of the proportion of students who graduate with science, engineering and technology degrees (undergraduate and postgraduate), data from the OECD shows that Ireland performs relatively well compared to other countries. In Ireland, 14.8% of the total number of graduates (undergraduate and postgraduate) in 2007 (the most recent year available) were awarded a science, engineering or technology degree. Please note that the categorisation of science, engineering and technology degrees includes a multitude of courses.²⁰

By ranking countries in accordance with the highest percentage of science graduates, this placed Ireland 3rd highest out of 29 countries. Only Germany (15.7%) and Austria (15.2%) had higher proportions of graduates with science, engineering and technology degrees, as shown in Figure 3.

Achievement

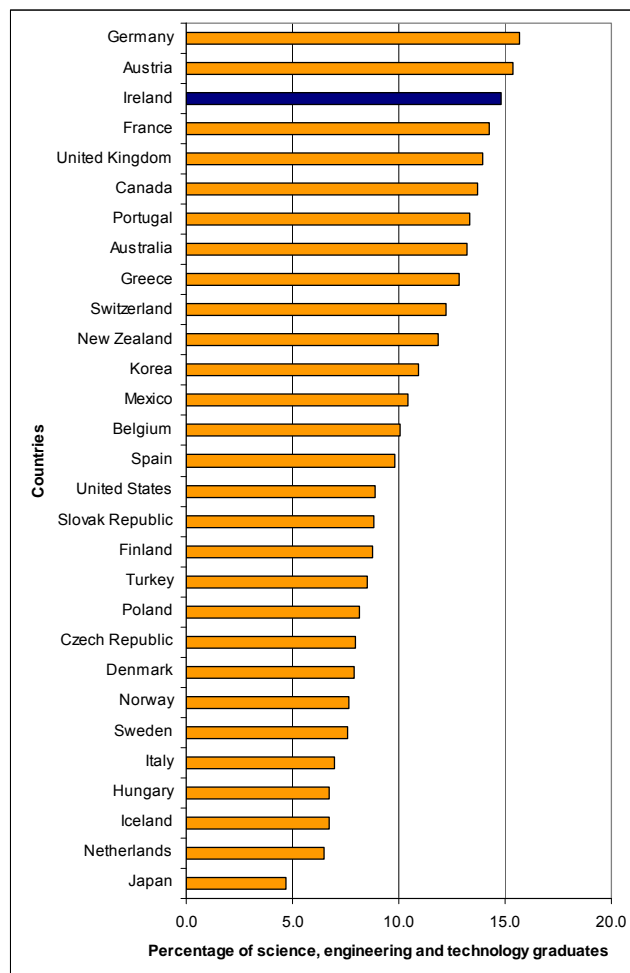
The Programme for International Student Assessment (PISA) is an international survey which provides a comparative assessment across 57 countries (OECD countries and partner countries) on the mathematical, scientific and reading literacy skills of 15-year olds. The scores and comparative performance of Ireland on the mathematical and scientific assessment is included in Appendix B.

In relation to science, the PISA analysis shows that Ireland’s average score of 508.3 is higher than the OECD average of 500. Ireland’s mean score is 20th highest of the 57 participating countries and the 14th highest of the 30 OECD

²⁰ Science, engineering and technology degrees include: science; life sciences; physical science; maths and statistics; computing; engineering and engineering trades; and, engineering, manufacturing and construction. Please note that this categorisation of science, engineering and technology degrees is not directly compatible with the categorisation used in Table 4 to determine science and applied science degree courses.

²¹ <http://stats.oecd.org/Index.aspx?DatasetCode=RGRADST>
Y

Figure 3: Percentage of students with a science, engineering and technology degree as a proportion of the total number of graduates (undergraduate and postgraduate), 2007.



Source: OECD²¹

countries. Analysis of previous PISA scores demonstrates that Ireland has consistently remained above the OECD average, as shown in Table 5 (overleaf).

In interpreting the 2006 results, Eivers *et al* (2007) argue that many aspects of the science performance in Ireland are encouraging. For example, Ireland has proportionally fewer students failing to reach the lower competency scales than the averages in other OECD countries.

On the other hand, Eivers *et al* (2007) suggest that there is room for improvement among higher-performing students. This is because Ireland’s slightly above average performance on science can be attributed to a proportionally smaller number of students (compared to other countries) achieving minimal scientific literacy standards. Ireland’s PISA score on the maths

scale is 501.5, which does not differ significantly from the OECD mean of 497.7. This score places Ireland 22nd highest of the 57 participating countries and the 16th highest of the OECD countries.

Analysis of the previous results shows that Ireland's average scores for maths have remained broadly the same from 2003 (the first year of the baseline) to 2006. In a similar finding to the science results, Eivers *et al* (2007) argue that lower achievers in maths in Ireland are doing well compared to other countries, but that higher achievers could do better.

Table 5: A comparison of Irish and OECD mean scores on scientific literacy 2000-2006

Year	Ireland	OECD average	Difference	Range of rank
2000	513.4	500.0	+13.4	9 th – 12 th of 27
2003	505.4	499.6	+5.8	9 th – 16 th of 29
2006	508.3	500.0	+8.3	10 th – 16 th of 30

Source: Eivers *et al* (2007)

Understanding Subject Choices

In Ireland, there is a long and wide-ranging debate about the reasons why many students do not go forward for examination in higher level maths, physics and chemistry in the Leaving Certificate, and why many students do not pursue these subjects at third level. In general, the key reasons presented in the debate can be grouped into five main themes. These are outlined below and examined in the subsequent paragraphs:

- Teaching methods and capacity.
- Subject specialisms.
- Curriculum.
- Career incentives.
- Educational resources.

Teaching methods and capacity

Some commentators argue that the reasons why many students do not go forward for examination in higher level maths rests with the skills and capacity of teachers and with the type of teaching methods.

Reflecting on the study of maths in schools, Childs (2006) argues that some of the teachers in Ireland are not adequately qualified. In support of this view, the EGFSN (2008) estimate that only around 20% of teachers of second-level mathematics studied maths as a major subject beyond the first year of their primary degree. The EGFSN (2008) also cites research, conducted by Department of Education and Science (DES) Inspectorate, which shows that a similar problem exists at primary school level. This 2005 report found that 28% of new primary teachers felt themselves to be 'poorly prepared' to teach mathematics.

In addition, the Royal Irish Academy (2008) highlights difficulties in regard to the skills of some science teachers. They state that one of the problems at Junior Certificate level is the lack of professional support for teachers with biology degrees who are also responsible for teaching other physical science subjects.

In terms of teaching methods, some concerns have been raised by commentators such as Oldham (2004) and Conway and Sloane (2005) that students are taught to compete well in maths and science exams rather than being taught to understand the subjects. Oldham argues that throughout the Leaving Certificate cycle, students are being prepared to pass exams in maths but are not given an understanding of maths or of how to apply mathematical concepts. As a result, many of these students can end up struggling to keep abreast of the workload at third level or apply their knowledge within the workplace environment. Indeed, this issue has also been highlighted in the Chief Examiner's report on Mathematics in 2005 which stated that weaknesses in teaching practices relate to:

'inadequate understanding of mathematical concepts and a consequent inability to apply familiar techniques in anything but the most familiar of contexts and presentations'.

The issue was highlighted again in a report conducted by the Educational Research Centre and the DES in 2006 which identified that 70% of school inspectors described teacher's knowledge of methods for teaching maths as 'somewhat limited' (cited by EGFSN, 2008).

Subject specialisms

Another of the major issues in the teaching and learning of science and maths is the perception that science and maths are specialist and particularly difficult subjects (EGFSN, 2008a). This perception stems from, in part, the fact that science and maths have their own unique languages (Childs, 2006).

In order to engage with the subjects, it is maintained that the unique languages of maths and science must be learned in addition to understanding the subjects themselves. This is considered to place a double burden on some students (Childs, 2006).

To emphasise some of the difficulties surrounding the learning of maths and science, the following text box highlights examples of the unique language of these subjects.

Text Box 1: Examples of the unique language in maths and science subjects

Science has a specialised vocabulary

e.g. molecule, ion, photosynthesis, refraction

Science uses familiar words with different meanings

e.g. equilibrium, energy, volatile

Science introduces a whole range of symbols and symbolic language

e.g. Hg, S, σ , Δ , Σ , \int

Science uses many logical connectives

e.g. consequently, conversely, respectively

Source: Childs (2006)

Curriculum

Concerns have been expressed that maths and science are not given sufficient priority within the school curriculum. While there is a compulsory maths subject called Mathematical Applications in the Leaving Certificate Applied, neither maths nor science is mandatory in the Established Leaving Certificate.

With most Leaving Certificate students studying seven or more subjects, the EGFSN (2008)

states able students (many of whom take seven subjects at this level) can treat mathematics as a 'spare' subject to be taken at ordinary level. The EGFSN (2008) argues that there is considerable anecdotal evidence that students are doing this in significant numbers.

In terms of science, not all schools offer these subjects at Leaving Certificate level and recent research suggests that the level of provision may actually decline. A survey, conducted by the Association of Secondary Teachers Ireland (ASTI), found that up to 25% of schools in some regions in Ireland have recently been forced to drop science from the curriculum due to cuts in teacher numbers.²²

Career incentives

Some commentators argue many students have poorly informed views of career opportunities arising from the study of these subjects (Royal Irish Academy, 2008). Indeed, while graduates in science can pursue a broad range of careers in sectors such as academia, venture capital, regulation, and the pharmaceutical, biotech and chemical industries, some concerns among students exist over the number and employment opportunities in these areas and their job security.²³

Furthermore, in current light of the current moratorium on public sector jobs and the threat to research-funded positions under the Report of the Special Group on Public Service Numbers and Expenditure Programmes (McCarthy report), some commentators have questioned the wisdom of educating people to PhD and post-doctoral levels in circumstances where the employment opportunities within the knowledge economy may be unclear.²⁴

²² Science and Maths Fall Victim to Cutbacks, *Irish Times*, 24th September 2009.
<http://www.irishtimes.com/newspaper/ireland/2009/0924/1224255129963.html>

²³ Choosing a career in science, *Irish Times*, 21st August, 2009
<http://www.irishtimes.com/newspaper/letters/2009/0821/1224253019354.html> Choosing a career in science, *Irish Times*, 24th August, 2009
<http://www.irishtimes.com/newspaper/letters/2009/0824/1224253139498.html> Choosing a fulfilling career is not rocket science, *Irish Times*, 13th August, 2009
<http://www.irishtimes.com/newspaper/opinion/2009/0813/1224252497204.html>

²⁴ McCarthy Call to Cut Science Funding Crass and Ill-informed, *Irish Times*, 18th August 2009,
<http://www.irishtimes.com/newspaper/opinion/2009/0818/1224252768970.html>

Indeed, research shows that a large proportion of science graduates go into further study or training. For example, a survey of the first destinations of UCD science students in 2007 shows that while 38% entered employment one year after graduation, 55% entered further study or training.²⁵

Educational resources

In the literature, concerns have been raised that the level of resources provided for the teaching of maths and particularly science is not sufficient and that this is impacting on educational outcomes. For instance, the Royal Irish Academy (2005) states that in many schools and universities, the laboratory equipment available for teaching science subjects is inadequate and/or obsolete. They go further by describing the quality and availability of laboratory equipment, in the context of what is expected of science in Ireland over the next decade, as being very poor.

Furthermore, the Royal Irish Academy (2009) maintains that within the education system, postgraduate studies at universities are receiving a disproportionate amount of finance. In a 2009 report, they argue that research at fourth level in Irish universities has received much higher levels of spending in recent years relative to teaching at third level.

According to the report, nearly €2 billion has been invested through Science Foundation Ireland (SFI) and the Programme for Research in Third-Level Institutions (PRTL). In comparison, the funding base for third-level education is considered to remain relatively low with the growth in student numbers actually leading to a decline in the level of resource per student.

A Way Forward?

With a view to understanding how participation levels in maths and science can be improved,

Science Cuts Could Do Serious Damage, Irish Times, 31st August, 2009

http://www.irishtimes.com/newspaper/innovation/2009/0831/1224253510984_pf.html

Choosing a career in science, *Irish Times*, 21st August, 2009

<http://www.irishtimes.com/newspaper/letters/2009/0821/1224253019354.html>

²⁵
<http://www.ucd.ie/t4cms/what%20social%20science%20graduates%20do.pdf>

this section draws together international best practice and expert recommendations, and identifies key initiatives that have recently been introduced in Ireland. The section is divided into five themes which are identified below and examined in the subsequent paragraphs:

- Teacher training.
- Teaching methods.
- Educational incentives.
- Curriculum development.
- New initiatives in Ireland.

Teacher training

Having conducted an analysis of high-performing education systems around the world, McKinsey and Company (2007) conclude that one of the main drivers of variance in educational outcomes is the quality of teachers. They argue that the best performing countries invest considerable resources in constantly improving their teachers' capability and that the quality of teaching maths and science is essential to improving proficiency.

In their study, McKinsey and Company cite Finland as one high performing educational system which places much emphasis on teacher training. In Finland, teachers are required to have a Master's postgraduate qualification and are prepared for a research-based profession. When appointed, teachers also must engage in a series of intensive life-long professional training programmes which promote various teaching practices as well as the science of effective learning. Overall, classroom teaching in Finland is considered a high status profession that recruits students from the top 10 percent of secondary students (Simola, 2005, Westbury et al., 2005).

In America, increased focus has also been placed on enhancing skills where teachers are required to receive up to 100 hours of in-service training per year to maintain an optimal standard of science teaching.

In Ireland, the ECFSN (2008) argue that more efforts need to be placed on upskilling maths and science teachers. They state that more time should be allocated for training and professional development and that professional Masters

degrees and high diplomas in maths education should be developed.

In a similar vein, the Royal Irish Academy (2008) has called for ring-fenced support for science education, better recognition for teaching taking part in science education initiatives and the introduction of positive action initiatives such as targeted efforts to recruit science graduates to undertake a Higher Diploma in education.

Teaching methods

Examples can be identified from other countries which have placed an increased emphasis on teaching students to solve problems, and understand and apply concepts in maths and science. The Netherlands, for example, has introduced an approach to the curriculum known as Realistic Mathematics Education (RME) which stresses the solution of problems that are set in particular contexts (EGFSN, 2008).

Similarly, in Finland, curriculum guidelines have placed problem-solving proficiency in maths and science as one of the primary goals of teaching. Overall, Sahlberg (2009) argues that secondary school in Finland can be characterised as having a strong focus on learning, creativity and various methods of studying rather than concentrating on passing tests and exams.

The promotion of a problem-solving approach to learning maths and science in Ireland has been supported by the EGFSN (2008). They argue that greater efforts need to be made to develop a more interactive, imaginative and interactive approach to teaching mathematics to help students understand maths concepts.

Educational incentives

At present, some debate exists within Ireland over whether students of maths and science should be awarded bonus points in the Leaving Certificate. The introduction of bonus points has been supported by business and industry groups who outline the importance of boosting student's interest in maths and science and incentivising the take up of these subjects.²⁶

The EGFSN (2008) has also recommended introducing incentives that include bonus college entry points for higher Leaving Certificate maths and allowing students the choice to take

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<http://www.ibec.ie/ibec/press/presspublicationsdoclib3.nsf/wvPCDCCC/B27AD91694B41C9F8025720B005500EA?OpenDocument>

ordinary level Leaving Certificate maths in their fifth year and higher level the year after.

While broadly supporting ways to incentivise students, the Royal Irish Academy (2008) argues that awarding bonus points may not be that effective as the number of points for many science, engineering and technology courses is relatively low. On this basis, they have highlighted enhancing the capacity of teachers and revising the curriculum as more pressing areas for change.²⁷

Curriculum development

In light of concerns over the provision of maths and science within the education system in Ireland, some commentators argue that these subjects should have greater emphasis within the curriculum in Ireland.

For instance, following a review of the take-up of science subjects at secondary school, the ESRI (2003) recommended that science should be made compulsory in the junior cycle, while the National Council for the Curriculum and Assessment (NCCA) has proposed that a scientific and engineering-based module should be included within the Leaving Certificate syllabus.²⁸

Some degree of consensus also exists among commentators in Ireland to develop a more integrated approach to teaching maths and science throughout the education system. The Royal Irish Academy (2009) argues that the syllabus should be aligned into cross-cutting strands (including, among other things, logical analysis and problem solving) which run from the primary to the senior cycle. It is held that this approach will provide a clearer articulation of the curriculum across important transition points such as the junior cycle to senior cycle.²⁹

The EGFSN (2008) has also recommended that more attention should be focused on students who struggle with maths to provide them with greater help at primary and junior level to reduce the numbers failing maths at Leaving Certificate.

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[http://www.ria.ie/policy/pdfs/Submission%20on%20Bonus%20Points%20for%20Maths%20\(29%20Feb%202008\).pdf](http://www.ria.ie/policy/pdfs/Submission%20on%20Bonus%20Points%20for%20Maths%20(29%20Feb%202008).pdf)

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<http://www.eapn.ie/notices/731>

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<http://www.ria.ie/policy/pdfs/Submission%20by%20RIA%20Mathematical%20Sciences%20Committee.pdf>

New initiatives in the maths and science curricula

There is ongoing review of education curricula in Ireland and currently both maths and science curricula are undergoing changes that are currently being tested by the Department of Education and Science, as outlined in the subsequent paragraphs.

Project Maths

At present, a new curriculum for teaching maths at secondary school is being piloted called *Project Maths*. According to the EGFSN (2008), *Project Maths* is an ambitious strategy for post-primary schools with an increased emphasis on problem-solving skills, and context and application. Within this project, maths syllabuses will be developed under five strand headings, all of which will be introduced into schools nationwide on a phased basis. The five strand headings are:

1. Statistics and probability
2. Geometry and trigonometry
3. Number
4. Algebra
5. Functions

The aim of the new initiative is to ensure that student's learning from the new *Project Maths* will experience maths, examples and applications, in ways that are meaningful for them. These examples and applications are designed to enable students appreciate how mathematics relates to everyday life and to the world of work.³⁰

Under the project, the implementation of syllabus change will be accompanied by teacher professional development, the provision of classroom support materials and incremental reform of mathematics examinations. In order to provide better continuity with primary school mathematics, a bridging framework is also being developed that will link the various strands of primary school mathematics with the topics on the Junior Certificate mathematics syllabuses.

Twenty-four second level schools are participating in the development stages of the syllabus revision and it is expected the initiative will be rolled out to all schools from late 2010 onwards.

³⁰ www.projectmaths.ie

The science curriculum

In 2003, the National Council for Curriculum and Assessment (NCCA) introduced a new curriculum for the teaching and assessment of science in the Junior Certificate. Among the major changes was an increased emphasis on scientific investigation and the application of scientific processes.

At present, the NCCA is working to revise the syllabuses in Leaving Certificate Biology, Chemistry and Physics. As part of this review, the NCCA has proposed changes in the area of assessment with a greater emphasis being placed on practical as well as theoretical examination.³¹ This aims to ensure that students will develop deeper levels of knowledge and understanding of science, scientific processes and scientific applications. New methods of assessment are currently being tested with students and teachers.

It is still too early in the life of these new maths and science initiatives to provide any assessment on their effectiveness.

Conclusions

This *Spotlight* has examined provision, participation and achievement in maths and science education in Ireland. In particular, the *Spotlight* has identified low levels of participation in physics, chemistry and maths in higher level examination papers. It also highlights that when compared to other countries, there is room for improvement among the higher achievers in these subjects. Reflecting on international research, the *Spotlight* shows that these trends in participation levels in maths and science are also evident in many other countries.

With a view to looking forward, the *Spotlight* has identified ways to increase participation levels in higher level examinations in maths and science. These include: giving maths and science greater emphasis in the curriculum; incentivising students to take up these subjects at second and third level; and, more particularly, changing teaching methods and enhancing the skills of teachers.

³¹ <http://www.curriculumonline.ie/en/Post-Primary-Curriculum/Junior-Cycle-Curriculum>

Appendix A: Achievement in Maths and Science at Second Level

Table A.1: Achievements in Junior Certificate maths (percentages rounded) 2006-2008

Level	Year	Total no. of students	Grade achieved			
			A %	B %	C %	Other ³² %
Higher						
	2008	23,634	17	32	32	19
	2007	23,804	18	30	28	24
	2006	24,205	18	32	29	21
Foundation						
	2008	26,384	12	36	29	23
	2007	27,094	9	33	31	26
	2006	26,820	13	37	28	16
Ordinary						
	2008	5,140	18	36	28	22
	2007	5,641	16	33	31	21
	2006	5,941	17	38	29	16

Source: State Examinations Commission (2009)³³

Table A.2: Achievements in Junior Certificate science (revised syllabus) (percentages rounded)³⁴ 2006-2008

Level	Year	Total no. of students	Grade achieved			
			A %	B %	C %	Other ³⁵ %
Higher						
	2008	33,566	8	30	41	21
	2007	34,855	10	31	37	22
	2006	30,580	10	32	39	29
Foundation						
	2008	14,125	3	37	43	15
	2007	14,892	3	35	41	21
	2006	14,676	1	24	47	28

Source: State Examinations Commission (2009)³⁶

³² D, E, F and NG

³³ http://www.examinations.ie/statistics/statistics_2008/JC_2006-2008_all.pdf

³⁴ Achievement levels for Junior Certificate Science Foundation Level are not available from the State Examinations Commission see http://www.examinations.ie/statistics/statistics_2008/JC_2006-2008_all.pdf

³⁵ D, E, F and NG

³⁶ http://www.examinations.ie/statistics/statistics_2008/JC_2006-2008_all.pdf

Table A.3: Achievements in Leaving Certificate maths (grades aggregated / percentages rounded) 2006-2008

Level	Year	Total no. of students	Grade achieved			
			A %	B %	C %	Other ³⁷ %
Higher						
	2008	8,510	15	31	33	21
	2007	8,388	16	34	31	4
	2006	9,018	14	35	33	18
Foundation						
	2008	35,808	13	28	27	33
	2007	35,077	14	28	26	31
	2006	35,113	12	27	27	34
Ordinary						
	2008	5,803	10	35	32	24
	2007	5,579	10	34	31	25
	2006	5,104	8	31	35	28

Source: State Examinations Commission (2009)³⁸

Table A.4: Achievements in Leaving Certificate science subjects (grades aggregated / percentages rounded)

Level	Year	Total no. of students	Grade achieved			
			A %	B %	C %	Other ³⁹ %
Higher						
	2008	29,609	22	28	24	26
	2007	32,129	21	28	25	25
	2006	28,421	18	27	26	29
Ordinary						
	2008	11,823	9	26	28	37
	2007	11,640	7	24	29	40
	2006	11,455	7	26	30	37

Source: State Examinations Commission (2009)⁴⁰

³⁷ D, E, F and NG

³⁸ http://www.examinations.ie/statistics/statistics_2008/JC_2006-2008_all.pdf

³⁹ D, E, F and NG

⁴⁰ http://www.examinations.ie/statistics/statistics_2008/JC_2006-2008_all.pdf

Appendix B: PISA Assessment 2006

Table B.1: Mean country scores for science and maths in PISA 2006

Science		Maths	
Country	Mean score	Country	Mean score
Finland	563.3	Chinese Taipei	549.4
Hong Kong-Ch	542.2	Finland	548.4
Canada	534.5	Hong Kong-Ch	547.5
Chinese Taipei	532.5	Korea	547.5
Estonia	531.4	Netherlands	530.7
Japan	531.4	Switzerland	529.7
New Zealand	530.4	Canada	527
Australia	526.9	Macao-China	525
Netherlands	524.9	Liechtenstein	525
Liechtenstein	522.2	Japan	523.1
Korea	522.1	New Zealand	522
Slovenia	518.8	Belgium	520.3
Germany	515.6	Australia	519.9
UK	514.8	Estonia	514.6
Czech Republic	512.9	Denmark	513
Switzerland	511.5	Czech Republic	509.9
Macao-China	510.8	Iceland	505.5
Austria	510.8	Austria	505.5
Belgium	510.4	Slovenia	504.5
Ireland	508.3	Germany	503.8
Hungary	503.9	Sweden	502.4
Sweden	503.3	Ireland	501.5
OECD Mean	500	OECD Mean	497.7
Poland	497.8	France	495.5
Denmark	495.9	UK	495.5
France	495.2	Poland	495.4
Croatia	493.2	Slovak Republic	492.1
Iceland	490.8	Hungary	490.9
Latvia	489.5	Luxembourg	490
United States	488.9	Norway	489.8
Slovak Republic	488.4	Lithuania	486.4
Spain	488.4	Latvia	486.2
Lithuania	488	Spain	480
Norway	486.5	Azerbaijan	476
Luxembourg	486.3	Russian Fed.	475.7
Russian Fed.	479.5	United States	474.4
Italy	475.4	Croatia	467.2
Portugal	474.3	Portugal	466.2
Greece	473.4	Italy	461.7
Israel	473.9	Greece	459.2
Chile	438.2	Israel	441.9
Serbia	435.6	Serbia	435.4
Bulgaria	434.1	Uruguay	426.8
Uruguay	428.1	Turkey	423.9

Science		Maths	
Country	Mean score	Country	Mean score
Turkey	423.8	Thailand	417.1
Jordan	422	Romania	414.8
Thailand	421	Bulgaria	413.4
Romania	418.4	Chile	411.4
Montenegro	411.8	Mexico	405.7
Mexico	409.7	Montenegro	399.3
Indonesia	393.5	Indonesia	391
Argentina	391.2	Jordan	384
Brazil	390.3	Argentina	381.3
Colombia	388	Colombia	370
Tunisia	385.5	Brazil	369.5
Azerbaijan	382.3	Tunisia	365.5
Qatar	349.3	Qatar	318
Kyrgyzstan	322	Kyrgyzstan	310.6

Source: cited by Eivers *et al* (2007)

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