Evidence for Excellence in Education

NFER Thinks

What the evidence tells us

Science education – have we overlooked what we are good at?

"Science is much more than a body of knowledge. It is a way of thinking."

(Sagan, 1990)

Education is vital to the UK's economic prosperity, especially science, technology, engineering and mathematics (STEM) education. As our engineering and science industries turn over approximately £257bn a year (CBI, 2010), the stakes are too high to risk damaging our science education system.

The government's proposed reforms to GCSE science are intended to ensure that England's science provision pre-16 is challenging and that it produces young people with the skills needed for future economic success. NFER warns that in implementing these reforms we may overlook many of the successful features of our existing science provision, and may be too quick to 'borrow' international policy solutions from other countries. We argue for a scientific approach to the reform of our science curriculum.

Internationally, a high value is currently placed on the English education system: in 2011 education exports were worth £17.5bn to the UK (BIS, 2013). Education is vital to the UK economy, and science, technology, engineering and mathematics (STEM) education in particular is essential for our economic prosperity. This makes the stakes too high to risk damaging our science education system.

The proposed reforms to GCSE science (which have just been through a process of consultation) (DfE, 2013a; Ofqual, 2013) are intended to ensure that England's science provision pre-16 is challenging and that it creates young people with the skills needed for future economic success. However, NFER is concerned that in implementing the reforms we may overlook many of the successful features of our existing science provision, and may be too quick to 'borrow' international policy solutions from other countries. We argue for a scientific approach to the reform of our science curriculum.

Sparking interest and achievement in science from an early age is important if young people are to be encouraged to continue studying science and to enter careers in science, technology, engineering and mathematics (STEM):

"For any politician anxious to ensure the next generation enjoy opportunities to flourish in an economy that is growing, in a nation that is confident and in a society that believes in progress, there is no escaping the centrality of mathematics and science."
(Gove, 2011)

In this paper we argue that:

- reform of the science curriculum and qualifications system in England should be made *scientifically* – by evaluating evidence about our existing provision and using it to engineer improvements; rather than by tinkering and losing all that is good in our current provision
- our students are more likely than many of their international counterparts to aspire to a job involving science, but this transition is often not made. The international surveys highlight positive student attitudes to science but these do not translate into take up of further study or careers in STEM. Based on the timing of the surveys we can conclude that disengagement happens after GCSE (and possibly during A level)
- we need to retain the happy balance of skills, knowledge and engagement that we currently have in our school students (which seems to be matched only by Hong Kong and Singapore)
- a knee-jerk reaction to reform of the science GCSE looks to be precipitous and risky, and is not necessarily the answer to enhancing STEM continuation rates post-16, or to improving student engagement and achievement pre-16.

How does England perform internationally?

A message that may be surprising to many is that England performs relatively well in international surveys, and can be considered among the 'world class'. Looking at the most recent Trends in International Mathematics and Science Study (TIMSS) results,[1] England is clearly in the band of countries doing well (see **Figure 1** for a selection of countries).

In reading this table, we need to be aware that making international comparisons is a complex affair – not least because educational outcomes are strongly linked to socio-economic context. England is a large, economically, culturally and socially diverse country; which is not true of all other countries in the high-performing group.

Further positive evidence is seen in the Programme for International Student Assessment (PISA) 2006 results;[2] just seven countries had mean scores for science that were significantly higher than those of England (Bradshaw et al., 2007). This further reinforces the message of success for England in terms of science performance.

How do our highest achievers perform?

The TIMSS data has four international benchmarks of achievement: Advanced, High, Intermediate and Low. **Figure 2** shows the percentages of students reaching the international benchmarks in a selection of countries. In England, 14 per cent of year 9 students reached at least the highest benchmarks bettered only by Singapore, Taiwan, Korea and Japan.

England also has a significant proportion of young people (7 per cent) who fail to meet the lowest benchmark for achievement in science – a figure which should not be overlooked when planning reform. This highlights the importance, as argued in our *NFER Thinks* on mathematics (Whitehouse and Burdett, 2013), of developing a curriculum that caters for all strands of the ability spectrum; to stretch our highest achievers, but to ensure that our lowest achievers are not ignored.

Making sure we have the right balance of knowledge and skills

And it is not just about overall achievement – we need to make sure that our science curriculum not only delivers students who 'know facts' but also young people who understand and can use that knowledge. England performs statistically better at 'reasoning' – that is, skills such as comparing, contrasting, classifying, relating, interpreting information and explaining – than just recall. The science curriculum in England has a good balance of skills to knowledge, which many other countries fail to achieve.

At a time when we seem to be putting more content into our science subject criteria (DfE, 2013b), Singapore (Ministry of Education, 1998) has actively reduced content to allow more time for the teaching of higher order reasoning skills, and more recently, Hong Kong is thinking of doing this (LegCo, 2013).

---

1 Unless otherwise stated, all data included is taken from TIMSS 2011 (IEA, 2013a).

2 2006 was the most recent year in which PISA had a specific focus on science.

Figure 1: Distribution of science achievement TIMSS 2011, 8th Grade data

Exhibit 1.2: Distribution of Science Achievement — TIMSS 2011 Science 8th Grade

Country	Average Scale Score
[2] Singapore	590 (4.3)
Chinese Taipei	564 (2.3)
Korea, Rep. of	560 (2.0)
Japan	558 (2.4)
Finland	552 (2.5)
Slovenia	543 (2.7)
[2] Russian Federation	542 (3.2)
Hong Kong SAR	535 (3.4)
‡ England	533 (4.9)
[2] United States	525 (2.6)
Hungary	522 (3.1)
Australia	519 (4.8)
[3] Israel	516 (4.0)
[1] Lithuania	514 (2.6)
New Zealand	512 (4.6)
Sweden	509 (2.5)

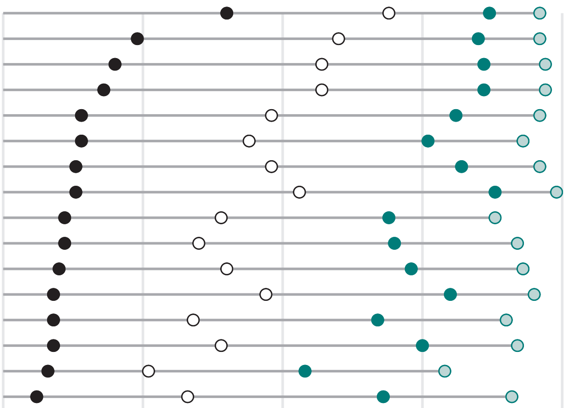
Science Achievement Distribution

(Source: IEA, 2013b) Extract from Exhibit 1.2. © 2013 International Association for the Evaluation of Educational Achievement (IEA)

Figure 2: Performance at the International Benchmarks of Science Achievement, TIMSS 2011

Exhibit 2.18: Performance at the International Benchmarks of Science Achievement — TIMSS 2011 Science 8th Grade

Percentages of Students Reaching International Benchmarks (● Advanced ○ High ● Intermediate ○ Low)



Country	Advanced Benchmark (625)	High Benchmark (550)	Intermediate Benchmark (475)	Low Benchmark (400)
[2] Singapore	40 (1.7)	69 (2.0)	87 (1.6)	96 (0.7)
Chinese Taipei	24 (1.4)	60 (1.2)	85 (0.8)	96 (0.4)
Korea, Rep. of	20 (0.9)	57 (1.1)	86 (0.7)	97 (0.4)
Japan	18 (1.1)	57 (1.3)	86 (0.9)	97 (0.4)
[2] Russian Federation	14 (1.1)	48 (1.8)	81 (1.2)	96 (0.7)
‡ England	14 (1.5)	44 (2.6)	76 (2.3)	93 (1.2)
Slovenia	13 (0.8)	48 (1.4)	82 (1.2)	96 (0.5)
Finland	13 (1.2)	53 (1.7)	88 (1.0)	99 (0.3)
[3] Israel	11 (1.1)	39 (1.7)	69 (1.7)	88 (1.1)
Australia	11 (1.6)	35 (2.5)	70 (2.0)	92 (0.8)
[2] United States	10 (0.7)	40 (1.3)	73 (1.1)	93 (0.7)
Hong Kong SAR	9 (1.1)	47 (1.8)	80 (1.7)	95 (1.0)
New Zealand	9 (1.0)	34 (2.2)	67 (2.2)	90 (1.2)
Hungary	9 (0.8)	39 (1.5)	75 (1.4)	92 (0.8)
Turkey	8 (0.9)	26 (1.4)	54 (1.4)	79 (1.0)
Sweden	6 (0.5)	33 (1.3)	68 (1.4)	91 (0.7)

(Source: IEA, 2013b) Extract from Exhibit 2.18. © 2013 International Association for the Evaluation of Educational Achievement (IEA).

Being the 'best'?

But science education is not just about good performance in tests; it is about sparking interest in science at an early age and encouraging young people to continue to study science.

A very positive message comes through when looking at attitudes to science in the TIMSS 2011 data (IEA, 2013b).

England has some of the highest scores in science engagement – higher than most other countries, especially the Organisation for Economic Co-operation and Development (OECD) and developed countries. Despite our top achievers being outperformed by a small group of Pacific Rim countries, high performance in these countries is not necessarily linked with students enjoying or wanting to study science.

This suggests we may not want to emulate these countries in the way we educate our pool of potential future scientists and engineers, despite their high achievement. Rather than blind 'policy borrowing' from the highest achieving countries, we should understand what we do well that others fail to do.

The data for England shows that:

- just 28 per cent of students 'wish they did **not** have to study science'. This compares to nearly half of students in Korea (48 per cent), 42 per cent in Taiwan, and 34 per cent in Japan. This is not just unique to these countries – in Australia, New Zealand and the United States, the percentages of students that wish they did not have to study science were also high, at just over 40 per cent.
- students believe their teacher gives them interesting things to do in their science lessons (74 per cent – compared to 31 per cent in Japan, 30 per cent in Korea, and 35 per cent in Taiwan).
- students are interested in what their science teacher is saying in their science lessons (76 per cent – compared to 52 per cent in Japan, 53 per cent in Korea, and 54 per cent in Taiwan).
- students agree they learn many interesting things in their science lessons (85 per cent – compared to 57 per cent in Japan, 70 per cent in Korea, and 72 per cent in Taiwan).

Our science education system compares well in terms of engagement, not just with the Pacific Rim, but also with Europe. This engagement is important if learners are going to make an effort to do well in science. Nearly all year 9 students who answered the TIMSS background questionnaire in England (92 per cent) agreed that it is important to do well in science.

The data from Taiwan, Korea and Japan suggests that high achievement, if not done carefully, comes at a high cost. And this cost is not just at the expense of learners; Japan and Korea ranked lowest of any countries in the survey for teacher satisfaction. Only 13 per cent of students in Korea were taught by teachers who were ‘satisfied’ with their careers.

Maintaining the balance between skills, achievement and engagement

Looking across the spectrum of countries there are very few that consistently have high achievement scores and also have positive feedback from students in terms of their enjoyment of/engagement with science. And most struggle to ensure that their students gain the necessary higher order skills to use their science knowledge. Along with England, only Hong Kong and Singapore can successfully claim to have struck this balance – indeed Singapore seems to have found a magic formula for very high achievement and engagement. Most other countries appear to struggle in engaging and motivating their students in learning science to a high achievement level.

Translating this enjoyment of science into future scientists

There is a gap in England between the positive attitudes that we know students hold regarding science up to GCSE level, and further study or STEM careers. As an earlier *NFER Thinks* article (Straw and Macleod, 2013) explained, although young people value mathematics and science education, many do not study STEM subjects beyond GCSE, and too few are currently inspired to pursue such choices beyond compulsory education. This is not a problem unique to England. Indeed, many countries struggle with this continuation of science-related pathways post-16 (DELNI and DENI, 2009).

The TIMSS data shows that around half of year 9 students in England (51 per cent) would like a job involving science (compared to 20 per cent in Japan and 30 per cent in Korea). The data suggests that the issue of lack of continuation is one that happens post-GCSE, although GCSE might well sow the seeds. We need to look carefully at why there is a mismatch between demand and supply in STEM. However, a knee-jerk reaction to reform of the science GCSE looks to be precipitous and risky, especially when the transition into science A level entries is steadily increasing (DfE, 2011).

Evidence-based decision-making

As we can see from the evidence on page 2, science education is not a single parameter, a single ranking, a single problem – it is a complex equation that needs thought and skill to address. We need to take a systemic approach and ensure that we come up with a science curriculum that addresses all the issues and continues to place England as a world leader in science education to which others continue to look.

If revisions are to be made to the key stage 4 science curriculum, these should be considered carefully in light of evidence such as this. Reform should not be made for the sake of reform; problem areas to focus on should be identified in a systematic and scientific way. We should use data to pinpoint where we perform well, and where improvements can be made.

We can look to other high-performing education systems (such as Singapore) for examples, but this should not be done at the expense of considering our own value as an effective system, and should be done cleverly, not blindly. What works in some contexts will not necessarily work in England – and simplistic ‘policy-borrowing’ is not the answer.

Conclusion

NFER believes that it is time to celebrate the successes of our science provision. We have achieved a rare hat trick in England – relatively high achievement in science backed up by the ability to use that knowledge, coupled with positive student attitudes towards learning science. We feel strongly that care should be taken during reform of the GCSE science curriculum to ensure that this balance is not disrupted and that young people are not deterred from enjoying the subject.

We need to celebrate the areas we are good at (the data suggests science teaching is one of these, even if we do need more specialist teachers (SCORE, 2011)), while using an evidence-based approach to identify the areas in which we need to improve.

More work needs to be done to ascertain how positive student attitudes towards science learning and STEM careers pre-16 can be sustained and translated into continuation post-16.

But we do not believe that a reform of the GCSE curriculum that fails to take into account the important evidence base around our science achievements is the best way to achieve this. We are pleased that the Department for Education (DfE) and Ofqual are consulting on how best to achieve better science education and look with interest to see how these consultations translate into practice.

References

Bradshaw, J., Sturman, L., Vappula, H., Ager, R. and Wheater, R. (2007). *Achievement of 15-year-olds in England: PISA 2006 National Report* (OECD Programme for International Student Assessment). Slough: NFER [online]. Available: www.nfer.ac.uk/nfer/publications/NPC02/NPC02.pdf [21 August 2013].

CBI (2010). *SET for Growth: Business Priorities for Science, Engineering and Technology* [online]. Available: www.cbi.org.uk/media/878512/16B6A4AD035FF3D88025778B0053D94D__20100801-set-for-growth.pdf [11 February 2013].

Department for Business, Innovation and Skills (2013). *International Education: Global Growth and Prosperity.* London: BIS [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225607/bis-13-1081-international-education-global-growth-and-prosperity.pdf [21 August 2013].

Department for Education (2011). *Maths and Science Education: the Supply of High Achievers at A Level (Research Report 79).* London: DfE [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182261/DFE-RR079.pdf [21 August 2013].

Department for Education (2013a). *Reformed GCSE Subject Content Consultation.* London: DfE [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/206131/GCSE_subject_content_consulation_document_final.pdf [21 August 2013].

Department for Education (2013b). *Science: GCSE Subject Content and Assessment Objectives.* London: DfE [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211219/GCSE_Sciences_final_updated.pdf [21 August 2013].

Department of Employment and Learning and Department of Education (2009). *Report of the STEM Review (Science, Technology, Engineering and Mathematics)* [online]. Available: www.delni.gov.uk/report_of_the_stem_review.pdf [21 August 2013].

Gove, M. (2011) 'Michael Gove speaks to the Royal Society on maths and science.' Speech to The Royal Society, London, 29 June [online]. Available: https://www.gov.uk/government/speeches/michael-gove-speaks-to-the-royal-society-on-maths-and-science [21 August 2013].

International Association for the Evaluation of Educational Achievement (IEA) (2013a). *TIMSS 2011 Eighth Grade Almanacs* [online]. Available: http://timssandpirls.bc.edu/timss2011/downloads/T11_G8_Almanacs.zip [21 August 2013].

International Association for the Evaluation of Educational Achievement (IEA) (2013b). *TIMSS 2011 International Database [online]. Available:* http://timssandpirls.bc.edu/timss2011/international-database.html [21 August 2013].

Legislative Council of the Hong Kong Special Administrative Region of the People's Republic of China (2013). *Panel on Education: Meeting on 30 May 2013. Background Brief on Issues Related to the Review of the Implementation of New Senior Secondary Curriculum and Assessment (Paper No. CB(4)685/12-13(02)). Hong Kong: Legislative Council Secretariat* [online]. Available: www.legco.gov.hk/yr12-13/english/panels/ed/papers/ed0530cb4-685-2-e.pdf [21 August 2013].

Ministry of Education (1998). *Content Reduction in the Curriculum* [online]. Available: www.moe.gov.sg/media/press/1998/980716.htm [21 August 2013].

Office of Qualifications and Examinations Regulation (2013). *GCSE Reform Consultation.* Coventry: Ofqual [online]. *Available:* www.ofqual.gov.uk/files/2013-06-11-gcse-reform-consultation-june-2013.pdf [21 August 2013].

Sagan, C. (1990). 'Why we need to understand science', *The Skeptical Inquirer,* 14, 3 [online]. Available: https://docs.google.com/document/d/1WkBktcq4kewijVsjD90GCPmLwN_6EPqwJ_xxEwVubbw/edit?usp=sharing&pli=1 [21 August 2013].

SCORE (2011). *Subject Specialist Teaching in the Sciences: Definitions, Targets and Data. London: SCORE [online]. Available:* www.score-education.org/media/7987/spec-teach.pdf [21 August 2013].

Straw, S. and Macleod, S. (2013). *Improving young people's engagement with science, technology, engineering and mathematics (STEM) (NFER Thinks: What the evidence tells us).* Slough: NFER [online]. Available: www.nfer.ac.uk/nfer/publications/99927/99927.pdf [21 August 2013].

Whitehouse, G. and Burdett, N. (2013). *Why mathematics education needs whole-system, not piecemeal reform (NFER Thinks: What the evidence tells us).* Slough: NFER [online]. Available: www.nfer.ac.uk/nfer/publications/99933/99933.pdf [21 August 2013].

NFER

NFER is a charity with a reputation worldwide for providing independent and robust evidence for excellence in education and children's services. Our aim is to improve education and learning, and hence the lives of learners, by researching what is happening now. Our authoritative insights inform policy and practice, offering a unique perspective on today's educational challenges.

We work with an extensive network of organisations, all genuinely interested in making a difference to education and learners. Any surplus generated is reinvested in research projects to continue our work to improve the life chances of all learners from early years through to higher education.

Newman Burdett

Dr Newman Burdett is head of the Centre for International Comparisons. He is a scientist by background and an educational assessment expert with experience of conducting research, reviews and policy advice in both national and international contexts.

He is a fellow of the European Association for Educational Assessment. The Centre for International Comparisons manages the international comparisons conducted at NFER, including providing international benchmarking of educational initiatives for countries and organisations around the world and international surveys such as PISA, TIMSS and PIRLS.

His particular interests are national assessment policies, how to monitor educational outputs and how to compare national education systems and standards. He is also a specialist adviser to the House of Commons education committee.

Harriet Weaving

Harriet Weaving is a research manager based in the Centre for International Comparisons. Before joining NFER in 2012, she worked as a social researcher at the Department for Education (DfE).

Throughout her research career, Harriet has gained a variety of experience in terms of commissioning research projects and developing hands-on research skills. She has considerable experience in designing and managing a wide range of research and evaluation projects using qualitative, quantitative, desk research and review methods. She also has experience in synthesising research evidence on a range of educational issues.

Before DfE, Harriet worked in research and evaluation in the private and charity sectors.

Published September 2013

ISBN 978-1-908666-68-0

National Foundation for Educational Research
The Mere, Upton Park
Slough, Berks SL1 2DQ

T: 01753 574123
F: 01753 691632
E: enquiries@nfer.ac.uk
www.nfer.ac.uk