Research Report DFE-RR178

Review of the National Curriculum in England

What can we learn from the English, mathematics and science curricula of high-performing jurisdictions?

Department for Education

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Executive Summary

Introduction

The Government is committed to ensuring that the new National Curriculum compares favourably with the curricula in the highest performing jurisdictions, and sets rigorous requirements for pupil attainment which measure up to the highest standards set internationally. The Government is also committed to slimming the National Curriculum so that it properly reflects the body of essential knowledge which all pupils should learn.

The purpose of this report is to explore and present initial findings on what can be learned from the analysis of curricula of high-performing jurisdictions, in order to inform the development of the new National Curriculum for English, mathematics and science. In particular, issues of breadth, specificity and challenge within each subject are examined in detail to assess what this may tell us in devising a new National Curriculum which measures up to the highest international standards.

This report forms part of a suite of evidence documents gathered as part of the National Curriculum review, including the Expert Panel report and summary report of responses to the call for evidence. Further analysis is underway to examine the education systems and cultural contexts of high-performing jurisdictions, in order to assess what other factors need to be taken into account when comparing the relative achievement of pupils from different jurisdictions.

The first two sections of the report focus on the methodology and the achievement of pupils in England compared to other jurisdictions in reading, mathematics and science. The remaining three sections focus on English, mathematics and science respectively – including the analysis of breadth, specificity and challenge of the curricula in high-performing jurisdictions in comparison to the National Curriculum in England.

Achievement in international comparisons

An important perspective on England's educational performance can be gained from analysis of the results from international comparative assessments such as the Programme for International Student Assessment (PISA), the Progress in International Reading Literacy Study (PIRLS) and the Trends in International Mathematics and Science Study (TIMSS).

In the most recent waves of PISA, PIRLS and TIMSS, England's performance was average, or higher than the average, at each age tested for reading, mathematics and science. However, to raise standards so that England is on a par with the highest-performing jurisdictions in the world, it is necessary to focus on areas for improvement. For this reason, the following findings concentrate exclusively on areas where there is the most scope to improve England's performance in these international assessments.

- ***Reading:*** Areas of particular priority for improvement in England are *making straightforward inferences from specific ideas in a text* in primary; and *retrieving information from a text*, *integrating and interpreting information to demonstrate understanding* and in *interpreting continuous texts* in secondary.

  - ***Mathematics*****:** Areas of particular priority for improvement in England are *number* in both primary and secondary and *algebra* in secondary, although attainment is relatively low in most areas of mathematics compared with high-performing jurisdictions, including in mathematical processes such as recalling facts and solving problems.

  - ***Science*****:** Unlike in reading and mathematics, attainment in science is relatively high, although areas of improvement can be identified across all sciences in primary and secondary. Weaknesses can also be identified in scientific processes and enquiry such as *using models and explanations* and *using scientific evidence*.

Curriculum comparisons

For English, mathematics and science, five comparator jurisdictions were selected, based on a synthesis of results from the recent waves of PISA, PIRLS and TIMSS, alongside the findings of other studies. The jurisdictions were selected separately for each subject, although there are some jurisdictions that are examined for more than one subject.

English	Mathematics	Science
New South Wales, Australia	Finland	Victoria, Australia
Alberta, Canada	Flemish Belgium	Alberta, Canada
New Zealand	Hong Kong	Hong Kong
Singapore	Singapore	Singapore
Massachusetts, USA	Massachusetts, USA	Massachusetts, USA

Curriculum aims are a key feature of high-performing jurisdictions, and there is also a degree of commonality in aims between jurisdictions for all three subjects. This indicates that curriculum aims aligned with those of high-performing jurisdictions should be considered for the new National Curriculum for each subject.

There is a relatively high degree of commonality in the domains of knowledge for all three subjects, particularly with regard to mathematics and science. This indicates that the high-level content of the National Curriculum is broadly in line with those of high-performing jurisdictions.

The curricula analysed maintain breadth within each subject, with little evidence that some jurisdictions define expectations around a narrow core of knowledge within any one subject or for any particular age group. This indicates that – in curricular terms at least – high-performing jurisdictions do not sacrifice breadth for depth or challenge within each of the subjects.

The main points of comparison for each subject are:

- ***English:*** The curricula for English are the most diverse in terms of the content specified and how this content is presented, although a common feature is an emphasis on different modes of communication (*reading*, *writing*, *speaking and listening*) and *literature*.

- ***Mathematics:*** Mathematics curricula invariably include the domains of *number*, *geometry and measures*, and *data and statistics* during the primary phase, and this is extended to the domains of *algebra* and *probability* during the secondary phase. Mathematical processes related to *mental and written fluency*, *problem solving*, and *mathematical reasoning* are also standard domains, although their presentation within each curriculum varies.

- ***Science:*** Science curricula invariably include the domains of *biology*, *chemistry* and *physics* both in primary and secondary, plus scientific processes and enquiry such as *experimental methods and practices*. There is more variation in how the content is presented – either integrated or separately by domain. *Earth science* content features in all curricula though not always as a separate domain.

Within each subject, there is a very wide range in the specificity of content across the curricula from different high-performing jurisdictions. For mathematics and science, greater specificity provides a clearer basis to assess what should be taught and therefore what pupils are expected to learn. This was more difficult for English, where greater specificity did not provide a clearer basis to assess challenge.

Where the level of challenge could be assessed:

- ***English:*** Although English curricula are more difficult to assess in terms of challenge, examples can be identified where the approach differs significantly from the approach used in the 1999 and 2007 National Curricula for England.

- ***Mathematics:*** Some mathematics curricula of high-performing jurisdictions are much more challenging than the 1999 and 2007 National Curriculum for England, in particular on *number* and *algebra*, though *data and statistics* is slightly more challenging in England.

- ***Science:*** Science curricula of one or two high-performing jurisdictions are more challenging than the 1999 National Curriculum, for example in some elements of *biology* and *physics*, though England is more challenging in other domains. However, the secondary 2007 National Curriculum for England is not specific enough to assess the level of challenge.

These initial findings on specificity and challenge indicate that if the National

Curriculum for English, mathematics and science are each slimmed down, there would need to be sufficient detail to be clear about high expectations. In particular, the current secondary National Curriculum for England was radically slimmed down in 2007 and this lacks the required specificity with which to set high expectations.

A number of examples are provided in the report to show key differences between the National Curriculum and the curricula of high-performing jurisdictions. These illustrate where the new National Curriculum could be strengthened so that the content and expectations are on a par with the highest-performing jurisdictions.

Conclusions

These findings are subject to the limitations of the methodology used. In particular, these findings are to be reviewed in the light of an ongoing analysis of the education systems and cultural contexts of high-performing jurisdictions and how the intended curriculum impacts on the enacted curriculum as implemented by teachers in the classroom in each jurisdiction.

However, even this initial analysis makes clear that the National Curriculum can be much more ambitious in terms of expectations and standards for English, mathematics and science without sacrificing curricular breadth within these subjects. It is more uncertain whether this ambition is achievable by slimming down the current National Curriculum for these subjects, especially mathematics and science. These issues will therefore need to be examined further in considering the design of the new National Curriculum.

Section 1 – Comparing achievement and the role of the curriculum

1.1 Introduction

As part of its commitment to learning from other jurisdictions[1] to improve pupil achievement in England's schools, the Government is reviewing the National Curriculum to ensure that it is informed by the content, standards and expectations of the highest-performing jurisdictions internationally. Comparative studies have demonstrated that pupils in other jurisdictions are performing at a significantly higher level in key aspects of reading, mathematics and science. The Government is also committed to slimming down the National Curriculum so that it properly reflects the body of essential knowledge which all pupils should learn. The Government wants to avoid prescribing pedagogy through the National Curriculum so that teachers are given greater professional freedom over how they teach their pupils.

The purpose of this report is therefore to explore and present initial findings from an analysis of curricula of high-performing jurisdictions, in order to inform the development of the new National Curriculum for English, mathematics and science. In particular, issues of breadth, specificity and challenge within each subject are examined in detail to assess what this might tell us in the context of devising a new National Curriculum which measures up to the highest international standards.

The report is divided into five sections:

- This section sets out the rationale and methodology used for the statistical analysis of pupil attainment across high-performing jurisdictions, and the content analysis of the statutory curricula of a sub-set of these jurisdictions, alongside some of the limitations of the methodology.

- Section 2 provides a summary of the findings from the most recent comparative studies – namely the Programme for International Student Assessment (PISA) 2009, the Progress in International Reading Literacy Study (PIRLS) 2006 and the Trends in International Mathematics and Science Study (TIMSS) 2007 - and assesses the performance of pupils in England compared with pupils in other jurisdictions in reading, mathematics and science.

- In Sections 3 to 5, the content of the statutory curricula are examined in more detail for English, mathematics and science respectively. The purpose of these sections is to:

[1]Throughout this report the term "jurisdiction" has been used for brevity. This term relates to countries, territories, provinces, regions or states that have central responsibility for public education, including the statutory curriculum. The term encompasses both the public education system and the wider society served by the education system.

- identify a subset of high-performing comparator jurisdictions in each of reading, mathematics and science;

- analyse the curriculum content of the comparator jurisdictions in order to provide insights into the commonalities and differences in the curriculum content;

- focus specifically on the breadth, specificity and, where possible, the level of challenge and/or sequencing of content within comparable age-phases; and

- illustrate some of the specific differences in challenge between curricula, with a focus on content appears more challenging in high- performing jurisdictions.

1.2 Rationale

In England, the introduction of the National Curriculum is considered to have made a lasting impact on pupils' achievement, through – for example:

- setting higher overall expectations of young people (see Barber, 2002[2]; Hopkins, 2001[3]; and Tabberer, 1997[4]);

- reduced inappropriate repetition of content (see Chitty, 2004[5]; and Evangelou et al, 2008[6]); and

- more balanced coverage of content in the primary phase, particularly in science (see Harlen, 2008[7]).

The National Curriculum has been revised regularly since it was introduced, but without a clear focus on international comparisons. As set out in Case for Change[8] published alongside the White Paper The Importance of Teaching [9], highly effective education systems have been increasingly examining the likely needs of the future, and adopting a systematic approach to curriculum reform. This approach has included thorough examination of evidence about the needs of young people, benchmarking against other curricula internationally and taking care to avoid too frequent changes to the curriculum, instead establishing a cycle in which the curriculum may be thoroughly reviewed perhaps once a decade. In addition, setting high

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[2] Barber, M. (2002). *Crossing the bridge.* Association for Achievement and Improvement through Assessment.
[3] Hopkins, D. (2001). *School improvement for real.* London: Routledge.
[4] Tabberer, R. (1997). *Primary Education: expectations and provision.* National Foundation for Educational Research.
[5] Chitty. C. (2004). *Educational Policy in Britain.* London: Palgrave Macmillan.
[6] Evangelou, M. Taggart, B. Sylva, K. Melhuish, E. Sammons, P. and Siraj-Blatchford, I. (2008). *Effective Pre-school, Primary and Secondary Education 3-14 Project (EPPSE 3-14): What Makes a Successful Transition from Primary to Secondary School?* DCSF-RR019.
[7] Harlen, W. (2008). *Science as a key component of the primary curriculum: a rationale with policy implications.* Perspectives on Education 1 (Primary Science), 2008:4–18.
[8] Department for Education (2010a). *The Case for Change.* DFE-00564-2010.
[9] Department for Education (2010b). *The Importance of Teaching – The Schools White Paper* 2010. DFE-CM-7980.

expectations – sometimes alongside some form of external assessment – can improve achievement overall (see NCES, 2007[10]).

In the context of this greater consideration of international comparisons, the statistics clearly indicate that attainment in England could be substantially improved. Findings from the most recent waves of PISA, PIRLS and TIMSS broadly suggest that England's performance remains average, or higher than the average, at each age tested for reading, mathematics and science. However, with more and more jurisdictions joining between PISA 2000 and PISA 2009, England's relative ranking has gone down from 7th to 25th in reading, 8th to 28th in mathematics and from 4th to 16th in science[11].

In order to improve pupil attainment, Tim Oates[12] argues that a coherent and conceptually well defined statutory curriculum is a necessary though not sufficient condition. He also argues that a great deal can be learned from an analysis of the content, standards and expectations of high-performing jurisdictions so long as consideration is taken of both educational and societal and cultural contextual factors. There is also a growing evidence base about the impact of the statutory curriculum on educational performance, including performance in international comparison studies such as PISA, PIRLS and TIMSS.

Indeed, the statutory curriculum has a significant impact on the way teachers plan their school curriculum and what is actually taught (see Schmidt & Prawar, 2006[13]), and studies show that national control of the curriculum can result in higher test performance in international comparative assessments such as TIMSS (see Schmidt et al, 2001[14]). Internationally, curriculum reform is considered by policy makers to be one of the key levers for effecting change in what happens in the classroom and thereby improving outcomes (see Mourshed, Chijiloke and Barber, 2011[15]; Pepper, 2008[16]; Sargent et al 2010[17]). There is also a small but growing evidence base of content analysis of international curricula in English, mathematics and science, for example the work of Ruddock and Sainsbury (2008)[18].

[10] National Center for Education Statistics (2007). *Mapping 2005 state proficiency standards onto the NAEP scales* (NCES 2007–482). U.S. Department of Education, National Center for Education Statistics, Washington, DC: US Government Printing Office.

[11] For an analysis of some of the limitations of comparisons over time, see Jerrim, J. (2011). *England's "plummeting" PISA test scores between 2000 and 2009: Is the performance of our secondary school pupils really in relative decline?* London: Department of Quantitative Social Science, Institute of Education, University of London.

[12] Oates, T (2010). *Could do better: Using international comparisons to refine the National Curriculum in England* Cambridge: Cambridge Assessment.

[13] Schmidt W. & Prawat R. (2006). *Curriculum coherence and national control of education: issue or non-issue?* Journal of Curriculum Studies, vol3.8 no.6 pp 641-658.

[14] Schmidt, W. H., McKnight, C. C., Houang, R. T., Wang, H.-C., Wiley, D. E., Cogan, L. S. and Wolfe, R. G. (2001). *Why Schools Matter: A Cross-National Comparison of Curriculum and Learning* San Francisco, CA: Jossey-Bass.

[15] Mourshed, M., Chikioke, C. and Barber, M. (2011). *How the world's most improved school systems keep getting better*, McKinsey & Company.

[16] Pepper, D. (2008). *Primary curriculum change: directions of travel in 10 countries*. London: Qualifications and Curriculum Authority.

[17] Sargent, C, Anne Byrne, A., O'Donnell, S. and White E. (2010), *Curriculum review in the INCA countries*, INCA thematic probe: June 2010.

[18] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.

The evidence suggests that reform of the National Curriculum can have an impact on raising standards, so long as other reforms are put in place to ensure that the curriculum can be delivered effectively by teachers and the accountability system puts sufficient focus on the quality of teaching[19]. In this context, the rationale for focusing on the curricula of high-performing jurisdictions is that – alongside other factors – each of these curricula is part of an education system that works in practice. The key features of curricula associated with world class assessment results can therefore be assessed, and this is what this report sets out to achieve.

1.3 Methodology

The methodology used to produce this report is based on both a statistical analysis of data from recent waves of PISA, PIRLS and TIMSS and on content analysis of comparator curricula documents.

The statistical analysis included an analysis of the performance of pupils in England compared to pupils in high-performing jurisdictions in reading, mathematics and science. This analysis presents data from PISA, PIRLS and TIMSS studies, comparing the average scale scores of the high-performing comparator jurisdictions to those of England. The data are used to compare assessment scores that were statistically significantly different from those of England, focusing on those that were higher and lower than England, and those which had improved or deteriorated compared to their own score in the previous assessment wave. In addition, a more fine-grained analysis of pupil performance examines attainment in different domains of reading, mathematics and science. The statistical analysis is set out in Sections 2.4 to 2.6.

For the content analysis, all curricula reviewed were compared with the current National Curriculum for English, mathematics and science[20]. Curricula were analysed on a domain by domain basis in order to compare coverage and sequencing of content, adopting the methodology used in Ruddock and Sainsbury[17]. Wider research evidence has also been used to supplement the analyses in order to highlight key issues related to curriculum choices and the extent to which they relate to pedagogy. In terms of particular subjects, the framework of analysis for different domains of knowledge was as follows:

- For English, the analysis focused on the domains of *reading, writing, speaking, listening* and *language structure*; each was sub-divided into respective sub-domains.

- For mathematics, the analysis focused on the domains of *number, fractions, algebra, statistics* and *probability*, alongside domains related

[19] Department for Education (2010a). *The Case for Change.* DFE-00564-2010.
[20] The current primary level National Curriculum (Key Stages 1 and 2) was released in 1999 alongside the secondary National Curriculum (Key Stages 3 and 4). The secondary level National Curriculum was subsequently revised in 2005 for Key Stage 4 science and 2007 for Key Stage 3 and 4 English and mathematics and Key Stage 3 science.

to *mathematical processes*.

- For science, the analysis focused on the sub-domains within *biology, chemistry* and *physics* alongside domains related to *scientific processes* and *enquiry*[21].

On the basis of the content analysis, some specific examples have been identified where the curricula of other jurisdictions were more challenging than the National Curriculum for England. These instances have been selected as illustrative examples and are not intended to be generally indicative of the level of challenge of that curriculum. For the reasons set out later in the report, comparing the level of challenge systematically as part of the analysis was not always possible.

Wherever possible, the analysis focused mainly on the statutory curricula in place during the late 1990s and/or 2000s. These were the curricula that would have defined expectations in schools for pupils who participated in PIRLS 2006, TIMSS 2007 or PISA 2009. Due to this historical approach, it should be noted that statutory curricula in some jurisdictions may have changed substantially since the curricula under consideration. Where there has been more recent reform, the analysis identifies the most substantive changes to the statutory curricula.

Thus, for England, the 1999 National Curriculum is likely to have had the most significant impact on the education of pupils in recent years, while the more recent 2007 National Curriculum for secondary was implemented between 2008 and 2011. The analysis therefore focuses primarily on the 1999 National Curriculum while only substantive changes since 2007 are identified. The analysis does not include wider non-statutory guidance and other related resources. For this reason, the National Strategies[22] frameworks and other non-statutory guidance in literacy, mathematics and secondary science introduced by the previous Government are not within the scope of this analysis.

Table 1.1 below sets out the comparator jurisdictions and the publication years of the statutory curricula that were introduced or revised over the 1990s and 2000s.

[21] The definition of domains and sub-domains was informed by the call for evidence response from Science Community Representing Education (SCORE) – see http://www.score-education.org/media/7650/scorencevidence.pdf. SCORE is a collaboration of organisations and comprises of the Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry and Society of Biology.

[22] The National Strategies website with the main resources can be found here: http://webarchive.nationalarchives.gov.uk/20110809101133/http://www.nsonline.org.uk

Table 1.1: Comparator jurisdictions and the publication date of the curricula used for comparison

	Curricula Examined – Date of Publication		
Jurisdiction	**Mathematics**	**English**	**Science**
England (primary & secondary)	1999	1999	1999
England (secondary only)	2007	2007	2005,2007
Alberta		2000, 2003	1996, 2003, 2005
Finland	2004		
Flemish Belgium	2010[23]		
Hong Kong	1999, 2000		1998, 2002, 2007
Massachusetts	2000, 2004	2001	2006
New South Wales		2003, 2007[24]	
New Zealand		1994	
Singapore	2001	2001	2001, 2005
Victoria			2008[25]

Mapping curriculum content against different age groups is one of the most technically challenging aspects of the content analysis. Table 1.2 shows how the different year groups in the comparator jurisdiction education systems have been mapped against the year groups used in England. Throughout the report, the England equivalent terms are used to describe particular year groups (e.g. Year 7) or age phases (e.g. Years 1-2).

For Hong Kong, slightly different equivalence has been used for mathematics and science. For mathematics, the closest age equivalence between England and Hong Kong is used in order to capture accurately and fairly the detailed year-on-year content in the primary phase in Hong Kong. For science, the closest key stage equivalence is used as this gives a better match at secondary level. This is because the Hong Kong science curriculum is relatively limited in the primary phase compared to the secondary phase, while the content itself is set out by their key stages rather than year-on-year. The result of the science equivalence basis is that pupils in Hong Kong deemed to be at the same stage are actually an average of eight months older than those in England.

[23] No statutory curriculum was available earlier than 2010.
[24] The 1998 New South Wales K-6 syllabus was re-published in 2007 to include foundation statements for each stage.
[25] 2008 was a revised edition from the learning standards first published in 2005.

Table 1.2: Ages and phases across education systems in the comparator jurisdictions

Age	England		Alberta		Massa-chusetts		New Zealand		N.S. Wales & Victoria		Singapore *		Hong Kong (for Maths) †		Hong Kong (for Science) ‡		Flemish Belgium		Finland	
4–5	EYFS	R		Preschool		Preschool		Preschool		Preschool		Preschool		K		K		Preschool		Preschool
5–6	Key Stage 1	Y1		K		K	Level 1	Y1	Early St. 1	K		K		K	Primary school	P1		Preschool		Preschool
6–7		Y2	Elementary school	G1	Elementary school	G1		Y2	Stage 1	Y1	Primary school	P1	Primary school	P1		P2	Primary school	P1		Preschool
7–8	Key Stage 2	Y3		G2		G2	Level 2	Y3		Y2		P2		P2		P3		P2	Phase 1	G1
8–9		Y4		G3		G3		Y4	Stage 2	Y3		P3		P3		P4		P3		G2
9–10		Y5		G4		G4	Level 3	Y5		Y4		P4		P4		P5		P4	Phase 2	G3
10–11		Y6		G5		G5		Y6	Stage 3	Y5		P5		P5		P6		P5		G4
11–12	Key Stage 3	Y7		G6		G6	Level 4	Y7		Y6		P6		P6	Secondary school	S1		P6		G5
12–13		Y8	Junior high school	G7	High school	G7		Y8	Stage 4	Y7	Secondary school	S1	Secondary school	S1		S2	First stage	S1	Phase 3 **	G6
13–14		Y9		G8		G8	Level 5	Y9		Y8		S2		S2		S3		S2		G7
14–15	Key Stage 4	Y10		G9		G9		Y10	Stage 5	Y9		S3		S3		S4	Second stage	S3		G8
15–16		Y11	H S	G10		G10	L 6	Y11		Y10		S4		S4		S5		S4		G9

═══ Phase transition (a point where most pupils would change school or start a different type of schooling)

(grey) Non-compulsory phase of education

* The express curriculum route was analysed as the majority of students (80%) take this route rather than the technical or academic route.

† For mathematics, the closest **age** equivalence between England and Hong Kong is used in order to accurately and fairly capture the structured nature of maths content in the primary years.

‡ For science, the closest **key stage** equivalence is used as this gives a better match at secondary level, which is where most science teaching takes place in Hong Kong.

Sources: http://education.alberta.ca/admin/resources/guidetoed.aspx, http://www.indobase.com/study-abroad/countries/usa/usa-education-system.html, http://www.minedu.govt.nz/, http://www.australianexplorer.com/australian_school_systems.htm, http://www.inca.org.uk/1018.html, http://www.edb.gov.hk/FileManager/EN/Content_1511/2012_poaleaflet_e.pdf, http://www.ond.vlaanderen.be/publicaties/2005/educationinflandersbroadview.pdf, http://www.uta.fi/FAST/US2/PAPS/ss-edfus.html

1.4 Further analysis

The analysis presented in this report does not encompass any examination of the education systems and societal factors that are often cited as explaining pupil achievement in different jurisdictions (see Alexander, 2001[26] and 2010[27]; Green, 1997[28]; National Research Council, 2003[29]; Oates, 2007[30] and 2010[31]; Wilkinson & Pickett, 2009[32]). To address this gap and build in the initial findings in this report, the Department for Education is analysing a wide range of factors that relate to both the given education system and the society served by this education system for a range of comparator jurisdictions. The particular factors that are currently being examined by the Department are:

- The cultural and demographic contexts of comparator jurisdictions. These contexts have been reviewed, noting differences in the size of the population and its linguistic make-up; in income levels and inequality; in teacher pay and qualification levels; and the levels of home-school involvement reported by head teachers;

- The structure of schooling in the comparator jurisdictions' education systems. Structures have been examined, including their levels of centralisation/decentralisation; the existence of a tiered or comprehensive secondary school system; the size and governance of independent and government-dependent private school sectors; and the direction of recent reforms to school structures;

- Accountability and assessment systems in the comparator jurisdictions' education systems. These have been compared with reference to the use of mandatory universal or sample testing; the level of governance at which accountability assessments are made; the focus on pupil, school or district-level performance; and the importance placed on differentiating pupil performance by different jurisdictions; and

- How the statutory curriculum is implemented in schools. This includes factors such as teaching time; breadth of the wider

[26] Alexander R.J. (2001). *Culture and Pedagogy: international comparisons in primary education* Oxford: Blackwell
[27] Alexander, R.J. (2010). *"World class schools" – noble aspiration or globalised hokum*. Compare: a Journal of Comparative Education Vol. 40 Issue 6 pp801-817.
[28] Green, A. (1997). *Education, Globalization and the Nation State*. London: Macmillan
[29] National Research Council. (2003). *Understanding Others, Educating Ourselves: Getting More from International Comparative Studies in Education*. Committee on a Framework and Long-term Research Agenda for International Comparative Education Studies. C. Chabbott and E. J. Elliott, editors. Board on International Comparative Studies in Education, Board on Testing and Assessment, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
[30] Oates, T. (2007), *The constraints on delivering public goods – a response to Randy Bennett's 'What does it mean to be a non-profit educational measurement organization in the 21st Century?'* International Association for Educational Assessment Annual Conference, Azerbaijan, September 2007.
[31] Oates, T (2010). *Could do better: Using international comparisons to refine the National Curriculum in England* Cambridge: Cambridge Assessment
[32] Wilkinson, R. and Pickett, K. (2009). *The Spirit Level: why equality is better for everyone*, London: Allen Lane.

curriculum and the differences between the intended and the actual curriculum in most state-funded schools.

Ultimately, in considering the development of the new National Curriculum, there is a need to articulate the relationship between the *intended* curriculum – as set out in any statutory curriculum – and the *enacted* curriculum - as experienced by pupils. This involves identifying a range of factors, including the critical role of school leaders and the extent to which teachers are given the skills, flexibility and incentives to go innovate and develop a school curriculum within which the intended curriculum is only a part.

Section 2 – Achievement in international comparison studies

2.1 Introduction

The transnational comparison of pupil attainment in this report is based on the data from the PISA, PIRLS and TIMSS studies (see Appendix 1 for background). Pupil attainment in different jurisdictions can be used as a means of identifying some as high-performing jurisdictions when compared with others, and for benchmarking system performance against what has been achieved internationally.

As the PISA, PIRLS and TIMSS studies are international in scope, cover large, randomly sampled groups of pupils and are administered to cohorts of specific age ranges, they are considered to be a reliable and robust comparison tool for performance against the subject areas tested in any particular wave.

However, as the studies are based on sample surveys, they do not test all the pupils in each participating jurisdiction, but instead assess a subset of each total pupil population. A further consideration is that different cohorts of pupils are sampled in the various assessments. However, the sampling strategy for each assessment sets out rigorous procedures to ensure that the samples tested have acceptable levels of representativeness[33]. Reporting of the results discloses any cases where sampling procedures within a particular participating jurisdiction failed to meet these standards.

Further caution is needed in comparing performance over time and between studies. For example, Jerrim[34] highlights changes in sampling methods over successive waves of PISA (e.g. from age based to year group based sampling), school and pupil response bias, and changes in the period of the year during which the survey is undertaken. In terms of comparison between studies, although the PISA, PIRLS and TIMSS studies all include an assessment of reading, mathematics and science, different kinds of knowledge are measured, meaning that the results are not directly comparable between PISA and PIRLS for reading or between PISA and TIMSS for mathematics or science. For example, TIMSS aims to discover what pupils have been taught and how much they know, while PISA aims to discover what pupils can do with the knowledge they have. There are other differences between PISA and the other studies, as highlighted by Ruddock *et al.*(2006)[35] who wrote:

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[33] See OECD (2010a). *PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science* (Volume I) pp22 Paris, OECD Publishing.
[34] Jerrim, J. (2011). *England's "plummeting" PISA test scores between 2000 and 2009: Is the performance of our secondary school pupils really in relative decline?* London: Department of Quantitative Social Science, Institute of Education, University of London
[35] Ruddock, G. Clausen-May, T. Purple, C. and Ager, R. (2006). *Validation Study of the PISA 2000, PISA 2003 and TIMSS 2003 International Studies of Pupil Attainment*. (p123). DfES Research Report RR772

It is the quantity of reading that marks PISA out, not the complexity of the language, which is similarly unfamiliar in both the international studies. The high reading demand of questions in PISA is often accompanied by a relatively lower demand in the mathematics or science required. This reflects the lower level of mathematics or science that pupils can apply in new contexts as opposed to very familiar ones.

Despite the fact that the TIMSS study focuses more on what pupils know rather than how they use this knowledge, TIMSS has published research that shows that there was no bias in test results caused by differences in curriculum in the education systems (see Martin *et al*, 2008[36]). Yet, given the differences between the studies, it is not surprising that two surveys can return quite different results in comparing between studies within any one jurisdiction and age group.

In summary, PISA, PIRLS and TIMSS studies can only provide a measure of performance for the subjects they test and - within reading, mathematics and science - the domains within each subject which are measured through the tests (see Appendix 1 for more detail). It is therefore not possible to directly compare the results of the different studies because they are measuring different things, at different ages, and for different pupil populations.

2.2 Key findings

- An important perspective on England's educational performance can be gained from analysis of the results from international comparative assessments such as PISA, PIRLS and TIMSS.
- However, comparisons between different international assessments must be interpreted with care; each study provides information on pupil performance which focuses on different aspects of subject knowledge, measured at different ages, and for different cohorts of pupils.

Reading

- Areas of particular priority for improvement in England are *making straightforward inferences from specific ideas* in a text in primary; and *retrieving information from a text*, *integrating and interpreting information to demonstrate understanding* and in interpreting *continuous texts* in secondary.
- At age 10, Alberta and Singapore scored higher than England in *interpreting ideas* and *making straightforward inferences* at a statistically significant level in the PIRLS 2006 study. At age 15,

[36] Martin, M.O; Mullis, I.V.S and Foy, P (with Olson, J.F; Erberber, E; Preuschoff, C and Galia, J) (2008). Appendix C of *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College

Singapore, New Zealand, Canada and Australia scored significantly higher than England in *retrieving, integrating and interpreting information* and *interpreting continuous texts* in the PISA 2009 study.

Mathematics

- Areas of particular priority for improvement in England are *number* in both primary and secondary and *algebra* in secondary, although attainment is relatively low in most areas of mathematics compared with high-performing jurisdictions.

- At age 10, Singapore, Hong Kong and Massachusetts scored higher than England at a statistically significant level in all mathematics domains; while at age 14 the same jurisdictions out-performed England in every area except *data and chance*, where only Singapore and Massachusetts scored significantly higher in the TIMSS 2007 study.

Science

- Unlike in reading and mathematics, attainment in science is relatively high, although areas of improvement can be identified across all sciences in primary and secondary. Weaknesses can also be identified in scientific processes and enquiry such as using models and explanations and using scientific evidence.

- At age 10 and 14, Singapore and to a lesser extent Massachusetts scored higher than England in most science domains, including *biology*, *earth science* and in the processes of science such as *recalling facts* and *using models and explanations* as measured in the TIMSS 2007 studies. At age 15, Hong Kong, Canada and to a lesser extent Australia outperformed the UK in most science domains such as *earth and space*, *physical systems* and *using scientific evidence* as measured in the PISA 2006 study.

2.3 Pupil attainment comparisons

The summary of aggregate scores for reading, mathematics and science provides a more general overview of pupil attainment in England in comparison with other jurisdictions. Table 2.1 provides a summary of the test score comparisons from recent waves of PISA, PIRLS and TIMSS studies for all jurisdictions with scores that were higher than England's at a statistically significant level on at least one scale across reading, mathematics and science. The table highlights in green jurisdiction scores that are statistically significantly higher than England or in yellow where there has been improvement since a previous wave of a study. The table also highlights in orange jurisdiction scores that are statistically significantly lower than England or where there has been significant deterioration since a previous wave of the study. Horizontal arrows (↔) indicate scores that are not statistically significantly different from England or from the same jurisdiction's score in the previous assessment wave, while ‘n/a’ indicates that data were not available to make the comparison.

In addition, for the PISA studies, England’s scores in reading, mathematics and science can be compared with other jurisdictions using the concept of years of progress[37]. Table 2.2 shows the attainment gap in terms of years of progress, effect size and PISA points for jurisdictions that performed statistically significantly better than England in PISA 2009.

Shanghai achieved the highest average scale scores across reading, mathematics and science in PISA 2009, and the attainment gap in terms of PISA points, effect size and years of progress for 15 year-old pupils in Shanghai and England is statistically significant in reading, mathematics and science. The attainment gap between reading scores for 15 year-old pupils in Shanghai and England was 62 points, which is equivalent to 1.5 years of progress. In mathematics, the gap was 108 PISA points, equivalent to 2.5 years of progress; and for science the gap was 61 PISA points, equivalent to 1.4 years of progress.

An example of where the picture differed between reading, mathematics and science can be seen in the achievement gap between pupils in England and Chinese Taipei. In mathematics, pupils in Chinese Taipei achieved an average scale score 51 points higher than pupils in England, equivalent to 1.2 years of progress. However for reading and science, the gap was not statistically significant.

In total, 15 year-olds in eight jurisdictions were found to have reading advantages equivalent to a year or more of progress when compared with English pupils (Shanghai, South Korea, Finland, Hong Kong, Singapore, Switzerland, Liechtenstein and Chinese Taipei). Three jurisdictions (Shanghai, South Korea and Finland) had advantages equivalent to at least one year’s progress in mathematics. In science, only Shanghai had an advantage equivalent to more than one year’s progress.

[37] In DfE analysis, a measure of years’ progress was derived using key stage point scores, with the point score at Key Stage 3 being closest to the age of PISA participants (15 years old). Years’ progress was then expressed in terms of effect size, which for Key Stage 3 was 0.4. For more detail see Education Standards Analysis and Research Division, Department for Education (2011). *PISA 2009 Study: How big is the gap? A comparison of pupil attainment in England with the top-performing countries*. DfE Research Report DFE-RR149.

Table 2.1: High-level comparisons of PISA, PIRLS and TIMSS scores compared with those of England

Subject	Reading				Maths						Science					
International Comparative Test	PIRLS 2006 age ≈ 10		PISA 2009 age ≈ 15		TIMSS 2007 age ≈ 10		TIMSS 2007 age ≈ 14		PISA 2009 age ≈ 15		TIMSS 2007 age ≈ 10		TIMSS 2007 age ≈ 14		PISA 2009 age ≈ 15	
Reference score for tests of statistically significant differences	Eng	2001 Test	Eng	2000 Test	Eng	2003 Test	Eng	2003 Test	Eng	2003 Test	Eng	2003 Test	Eng	2003 Test	Eng	2006 Test
Australia	n/a	n/a	▲	det	▼	imp	▼	↔	▲	det	▼	↔	▼	det	▲	↔
Belgium	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	▲	det	n/a	n/a	n/a	n/a	▼	↔
Belgium - Flemish	▲	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
British Columbia (Can)	▲	n/a	n/a	n/a	▼	n/a	↔	n/a	n/a	n/a	↔	n/a	▼	n/a	n/a	n/a
Canada	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	▲	↔
Canada - Alberta	▲	n/a	n/a	n/a	▼	n/a	n/a	n/a	n/a	n/a	↔	n/a	n/a	n/a	n/a	n/a
Denmark	▲	n/a	↔	↔	▼	n/a	n/a	n/a	▲	det	▼	n/a	n/a	n/a	▼	↔
Estonia	n/a	n/a	↔	n/a	n/a	n/a	n/a	n/a	▲	n/a	n/a	n/a	n/a	n/a	▲	↔
Finland	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	▲	det
Germany	▲	imp	↔	imp	▼	n/a	n/a	n/a	▲	imp	▼	n/a	n/a	n/a	↔	↔
Hong Kong (China)	▲	imp	▲	↔	▲	imp	▲	det	▲	↔	▲	imp	↔	det	▲	↔
Hungary	▲	imp	↔	imp	▼	det	↔	det	↔	↔	↔	↔	↔	↔	▼	↔
Iceland	▼	↔	↔	↔	n/a	n/a	n/a	n/a	▲	det	n/a	n/a	n/a	n/a	▼	↔
Italy	▲	imp	▼	↔	▼	↔	▼	↔	▼	imp	↔	imp	▼	↔	▼	imp
Japan	n/a	n/a	▲	↔	▲	↔	▲	↔	▲	↔	↔	↔	▲	↔	▲	↔
Korea	n/a	n/a	▲	imp	n/a	n/a	▲	imp	▲	↔	n/a	n/a	▲	det	▲	imp
Liechtenstein	n/a	n/a	↔	imp	n/a	n/a	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	↔	↔
Luxembourg	▲	n/a	▼	n/a	n/a	n/a	n/a	n/a	↔	↔	n/a	n/a	n/a	n/a	▼	↔
Macao (China)	n/a	n/a	▼	n/a	n/a	n/a	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	↔	↔
Netherlands	▲	det	▲	n/a	↔	↔	n/a	n/a	▲	det	▼	↔	n/a	n/a	↔	↔
New Zealand	▼	↔	▲	↔	▼	↔	n/a	n/a	▲	↔	▼	det	n/a	n/a	▲	↔
Norway	▼	↔	▲	↔	▼	imp	▼	imp	↔	↔	▼	imp	▼	det	▼	imp
Ontario – Canada	▲	↔	n/a	n/a	▼	↔	↔	↔	n/a	n/a	↔	↔	▼	↔	n/a	n/a
Russian Federation	▲	imp	▼	↔	↔	↔	↔	↔	▼	↔	↔	imp	▼	imp	▼	↔
Shanghai (China)	n/a	n/a	▲	n/a	n/a	n/a	n/a	n/a	▲	n/a	n/a	n/a	n/a	n/a	▲	n/a
Singapore	▲	imp	▲	n/a	▲	↔	▲	det	▲	n/a	▲	imp	▲	↔	▲	n/a
Slovenia	▼	imp	▼	n/a	▼	imp	▼	imp	▲	n/a	▼	imp	↔	imp	↔	det
Sweden	▲	det	↔	det	▼	n/a	▼	det	↔	det	▼	n/a	▼	det	▼	↔
Switzerland	n/a	n/a	↔	↔	n/a	n/a	n/a	n/a	▲	↔	n/a	n/a	n/a	n/a	↔	↔
Taipei (China)	↔	n/a	↔	n/a	▲	imp	▲	imp	▲	n/a	▲	imp	▲	det	↔	det
United States	↔	↔	↔	↔	▼	imp	↔	↔	↔	↔	↔	↔	▼	↔	▼	imp
US - Massachusetts	n/a	n/a	n/a	n/a	▲	n/a	▲	n/a	n/a	n/a	▲	n/a	▲	n/a	n/a	n/a

Key:	
▲	*Listed country has test score statistically significantly higher than England*
▼	*Listed country has test score statistically significantly lower than England*
↔	*Listed country has test score that is not statistically significantly different from England / its own score at the*
imp	*Listed country has test score that is statistically significantly higher than its own score at the previous test*
det	*Listed country has test score that is statistically significantly lower than its own score at the previous test*
n/a	*Data for the comparison not available*
Name	*Comparator education system, as listed in the following section*

Sources: Mullis, I.V.S. Martin, M.O. Kennedy, A.M. and Foy, P. (2007). *PIRLS 2006 International Report: IEA's Progress in International Reading Literacy Study in Primary Schools in 40 Countries*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston. OECD (2010a). *PISA 2009 Results: What Pupils Know and Can Do – Pupil Performance in Reading, Mathematics and Science* (Volume I). Paris, OECD Publishing. Mullis, I.V.S. Martin, M.O. and Foy, P. (with Olson, J.F. Preuschoff, C. Erberber, E. Arora, A. and Galia, J.) (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College. Martin, M.O. Mullis, I.V.S. and Foy, P. (with Olson, J.F. Erberber, E. Preuschoff, C. and Galia, C.) (2008). *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

Table 2.2: Attainment gap between England and jurisdictions outperforming England in PISA 2009 study

	Reading assessment			Mathematics assessment			Science assessment		
	Attainment gap…			Attainment gap…			Attainment gap…		
Comparison jurisdiction2	*Effect size*	…in PISA points	…in years' progress	*Effect size*	…in PISA points	…in years' progress	*Effect size*	…in PISA points	…in years' progress
Shanghai	*0.6*	62	1.5	*1.1*	108	2.5	*0.6*	61	1.4
South Korea	*0.5*	45	1.1	*0.6*	54	1.3	*0.3*	24	0.6
Finland	*0.4*	42	1.0	*0.5*	48	1.1	*0.4*	40	0.9
Hong Kong-China	*0.4*	39	0.9	*0.7*	62	1.5	*0.4*	35	0.8
Singapore	*0.3*	32	0.7	*0.7*	70	1.6	*0.3*	28	0.7
Canada	*0.3*	30	0.7	*0.4*	34	0.8	*0.2*	15	0.4
New Zealand	*0.3*	27	0.6	*0.3*	27	0.6	*0.2*	18	0.4
Japan	*0.3*	26	0.6	*0.4*	37	0.9	*0.3*	26	0.6
Australia	*0.2*	21	0.5	*0.2*	22	0.5	*0.1*	14	0.3
Netherlands	*0.1*	14	0.3	*0.4*	33	0.8	*0.1*	9	0.2
Belgium	*0.1*	12	0.3	*0.2*	23	0.5	-	-	-
Norway	*0.1*	9	0.2	*0.1*	6	0.1	-	-	-
Estonia	*0.1*	7	0.2	*0.2*	20	0.5	*0.1*	14	0.3
Switzerland	*0.1*	6	0.1	*0.4*	42	1.0	*0.0*	3	0.1
Iceland	*0.1*	6	0.1	*0.2*	14	0.3	-	-	-
Liechtenstein	*0.1*	5	0.1	*0.5*	44	1.0	*0.1*	6	0.1
Germany	*0.0*	3	0.1	*0.2*	20	0.5	*0.1*	7	0.2
Chinese Taipei	*0.0*	1	0.0	*0.5*	51	1.2	*0.1*	7	0.2
Denmark	*0.0*	1	0.0	*0.1*	11	0.3	-	-	-
Macao-China	-	-	-	*0.3*	33	0.8	-	-	-
Slovenia	-	-	-	*0.1*	9	0.2	-	-	-

1. Shaded cells indicate the gap between England's average score and that of the comparison jurisdiction is statistically significant.
2. Jurisdictions are listed in descending order by size of attainment gap in the reading assessment, those listed in **bold** are OECD member states.

\- Average score was not higher than England's in this strand.

Source: OECD, PISA 2009 Database and National Pupil Database 2010

Source: Education Standards Analysis and Research Division, Department for Education (2011). *PISA 2009 Study: How big is the gap? A comparison of pupil attainment in England with the top-performing countries*. DfE Research Report DFE-RR14

In Sections 2.4-2.6, pupil attainment in different domains of reading, mathematics and science is examined in more detail. In each case, the scales are set so that 500 is the mean (or very close to the mean), while the standard deviation – average distance from the mean – is 100. The error bars used on the charts show 95% confidence intervals – if it were possible to survey the whole population instead of just a sample, the result would very probably fall within these intervals. However, the mean and standard deviation depend entirely on the performance of the participating jurisdictions, and, since each survey has different participants, it is not possible to compare scale scores between different studies. In particular, PISA study scaling is based on the mean and standard deviation of OECD jurisdictions, while PIRLS and TIMSS use the mean and standard deviation of *all* participating jurisdictions.

2.4 International comparisons in reading

In the most recent waves of PISA and PIRLS, England's performance was average or higher than the average at each age tested for reading. The detailed findings set out below on different aspects of reading give a more fine-grained picture of pupils' achievement compared to other jurisdictions (see Appendix 1 for more details on how reading is measured). There are no large-scale international studies that assess other aspects of language or literacy such as writing.

Within reading, the three aspects of reading where there is most room for improvement in England are: *making straightforward inferences* in the primary curriculum from PIRLS 2006, and *access and retrieve*, *integrate and interpret* and the use of *continuous texts* in the secondary curriculum from PISA 2009. These findings are examined in more detail below:

Reading at age 10: PIRLS 2006

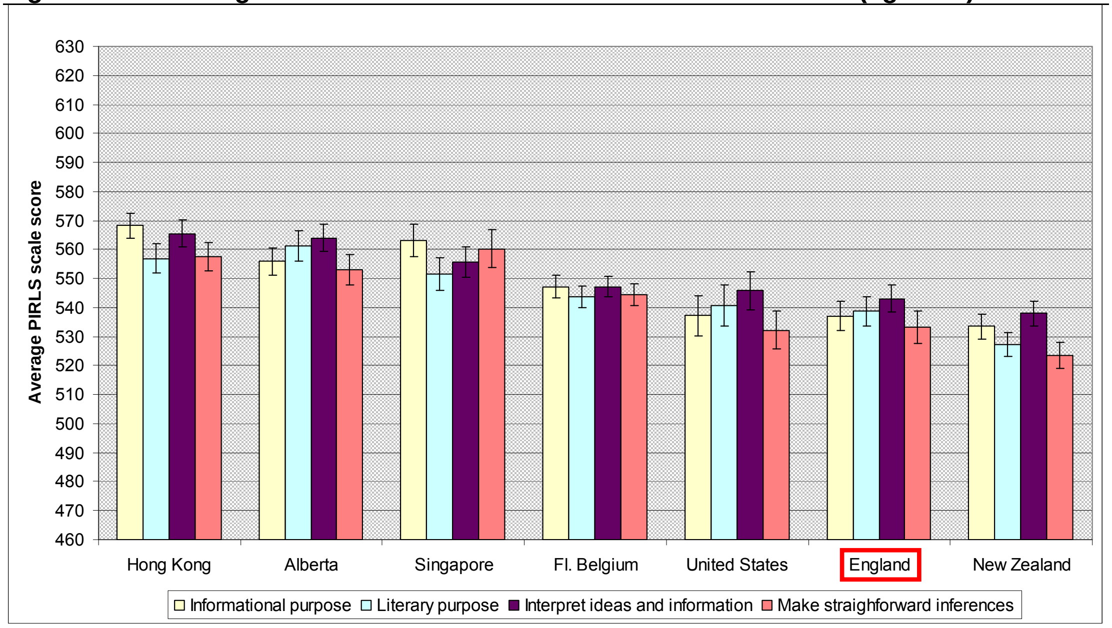
The PIRLS 2006 study tested reading for two different purposes: *literary* and *informational,* alongside testing for two different domains of reading:

- *interpreting ideas and information* involves whole-text and contextual understanding and response; and
- *making straightforward inferences* involves basic understanding of specific ideas in the texts.

As can be seen in Figure 2.3, pupils in Alberta and Singapore scored significantly higher than pupils in England in the tasks relating to *reading for informational purposes*. In addition, pupils also scored significantly higher in tasks relating to *reading for literary purposes* in Alberta and Singapore, although pupils in England scored significantly higher than those in New Zealand in this type of task. Scores for the US in both these domains were not significantly different to those for England.

In addition, pupils in Singapore and Alberta scored significantly higher in the *making straightforward inferences* domain; the score for pupils in the US was not significantly different to that of England. In the domain of *interpret ideas and information*, pupils in Alberta and Singapore achieved scores significantly higher than pupils in England. The scores for pupils in the US and New Zealand did not differ significantly to those for pupils in England in this domain.

Figure 2.3: Reading attainment for different domains in PIRLS 2006 (aged 10)



Note: Jurisdictions are shown in descending order of average reading achievement. Source: http://nces.ed.gov/surveys/international/ide/

Reading at age 15: PISA 2009

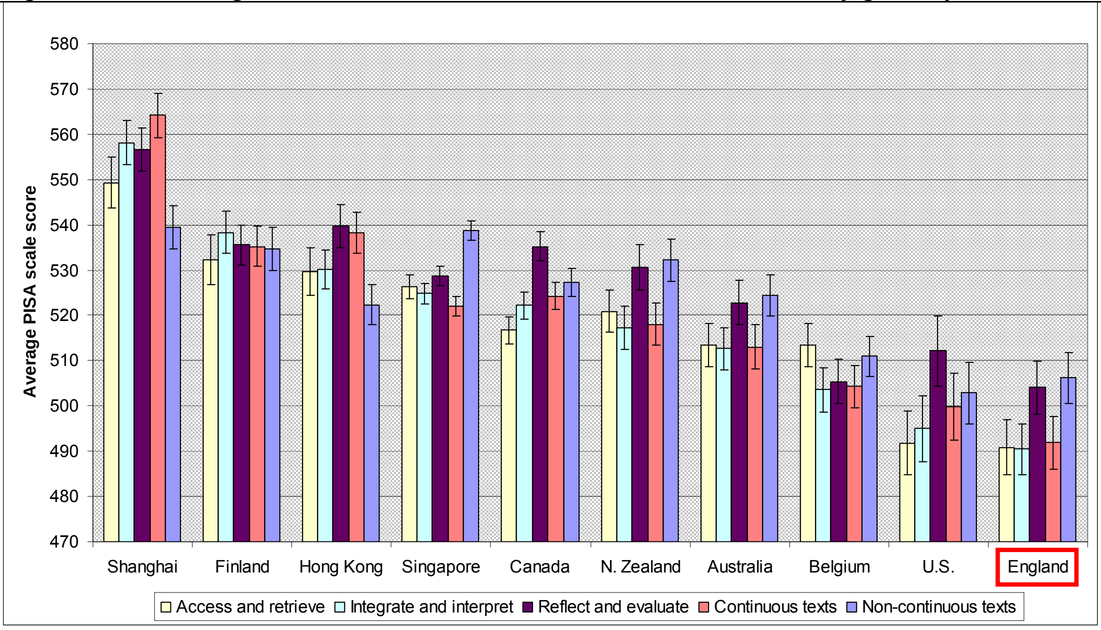
PISA 2009 tested for three different domains in relation to two different text formats – continuous and non-continuous. The three domains tested the ability to:

- *access and retrieve* information*;*
- *integrate and interpret* information in order to demonstrate understanding of the text; and
- *reflect on and evaluate* the text based on wider knowledge.

As can be seen in Figure 2.4, among Anglophone jurisdictions, pupils in Singapore, Canada, Australia and New Zealand scored significantly higher than 15 year old pupils in England on tasks relating to *accessing and retrieving information, integrating and interpreting information*, and *reflecting and evaluating*. Scores for pupils in the US for the three domains were not significantly different to those for pupils in England.

In addition, pupils in Singapore, Canada, Australia and New Zealand scored significantly higher than pupils in England on tasks relating to both *continuous and non-continuous texts*. As before, the scores for pupils in the US were not statistically significantly different to those achieved by pupils in England.

Figure 2.4: Reading attainment for different domains in PISA 2009 (aged 15)



Note: Jurisdictions are shown in descending order of average reading achievement. Source: http://nces.ed.gov/surveys/international/ide/

2.5 International comparisons in mathematics

In the most recent waves of the PISA and TIMSS studies, England's performance was average or higher than the average at each age tested for mathematics. The more detailed findings set out below on different aspects of mathematics gives a more fine-grained picture of pupils' achievement compared to other jurisdictions (see Appendix 1 for more details on how mathematics is measured).

Within mathematics, the domains where there is most room for improvement in England are *number* in both the primary and secondary curricula and *algebra* in the secondary curriculum, although attainment is relatively low in most of the domains of mathematics assessed. The findings are examined in more detail below.

Mathematics at age 10: TIMSS 2007

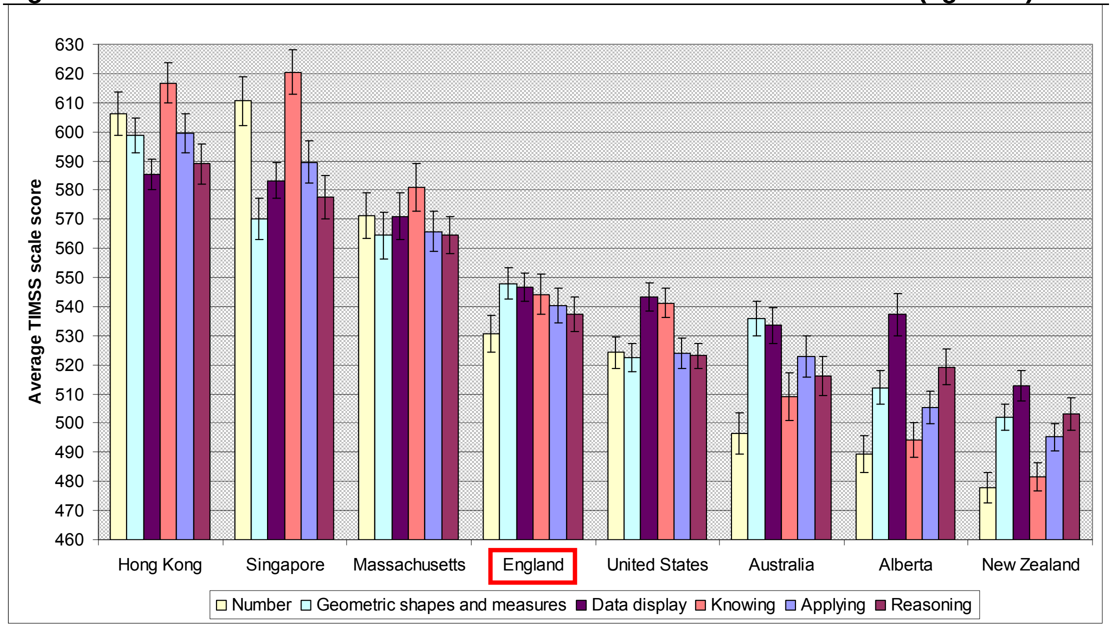
In mathematics at age 10, the TIMSS content domains were *number*, *algebra*, *geometric shapes and measures*, and *data display*. TIMSS 2007 also divided tasks into the cognitive domains of *knowing, applying* and *reasoning*. In mathematics:

- *knowing* means recalling facts and basic computation;
- *applying* means solving routine problems; and
- *reasoning* means solving non-routine problems.

As can be seen in Figure 2.5, there was a statistically significant difference between England and the higher-performing jurisdictions of Singapore, Hong Kong and Massachusetts in all of the six domains presented. England's scale score for the content domain of *number* (531) is lower than its other respective scores, suggesting greater weakness in this domain compared to geometric shape and measures or data display. At age 10, *number* typically involves tasks such as recognising multiples and factors of numbers; adding and subtracting fractions and decimals, number sentences and sequences. A relatively low score in *number* is shared by most of the English-speaking comparator jurisdictions with the exception of Massachusetts and the wider United States.

In the three cognitive domains, England's scores are quite similar to one another, while in Hong Kong, Singapore and Massachusetts pupils are much stronger in the cognitive domain of *knowing* in comparison with *applying* and *reasoning*.

Figure 2.5: Mathematics attainment for different domains in TIMSS 2007 (aged 10)



Note: Jurisdictions are shown in descending order of average mathematics achievement.
Source: http://nces.ed.gov/surveys/international/ide/

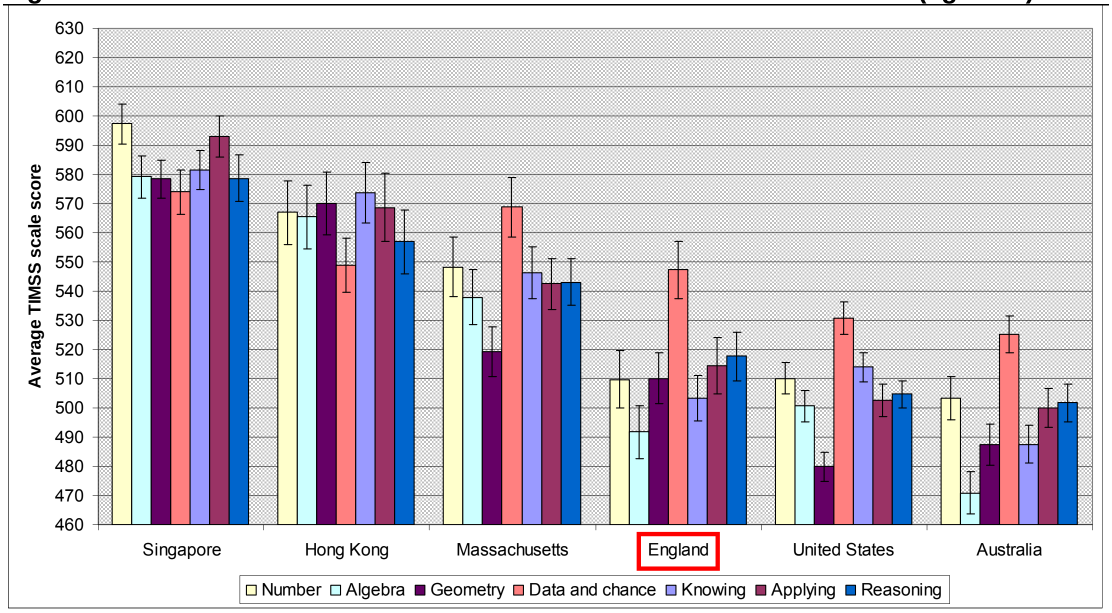
Mathematics at age 14: TIMSS 2007

In mathematics at age 14, the four content domains are *number*, *algebra*, *geometry*, and *data and chance* alongside the three cognitive domains of *knowing*, *applying* and *reasoning*.

As can be seen in Figure 2.6, in five of the seven domains, there was a statistically significant difference between England and each of the higher performing jurisdictions of Singapore, Hong Kong and Massachusetts. These were *number*, *algebra, knowing*, *applying* and *reasoning*. In *geometry* Singapore and Hong Kong significantly outperform England and Massachusetts while in *data and chance*, Singapore and Massachusetts significantly outperform England and Hong Kong.

In England, pupils' attainment in the domains of *number*, *algebra*, *geometry* and *data and chance* shows very high variation between domains compared to Singapore and Hong Kong, with the greatest difference between *data and* *chance* – where performance was relatively high - and *algebra.* This relatively low performance in *algebra* was on a par with the US but some way above Australia.

Figure 2.6: Mathematics attainment for different domains in TIMSS 2007 (aged 14)



Note: Jurisdictions are shown in descending order of average mathematics achievement.
Source: http://nces.ed.gov/surveys/international/ide/

2.6 International comparisons in science

Unlike in reading and mathematics, in the most recent waves of the PISA and TIMSS studies, England's performance was higher than the average at each age tested for science although a number of jurisdictions were higher performing at a statistically significant level. The more detailed findings set out below on different aspects of science gives a more fine-grained picture of pupils' achievement compared to other jurisdictions (see Appendix 1 for more details on how science is measured).

Within science, overall improvement is desirable in *biology*, *physics* and *chemistry* – alongside the *earth sciences*. No specific domains stand out as requiring particular improvement in either primary or secondary. Some weaknesses can be identified in scientific processes and enquiry such as using models and explanations and using scientific evidence. The findings are examined in more detail below.

Science at age 10: TIMSS 2007

The TIMSS age 10 content domains for science are *life science*, *physical science* and *earth science*. This means that chemistry and physics are combined in TIMSS (under *physical science*), while *earth science* is a separate domain.

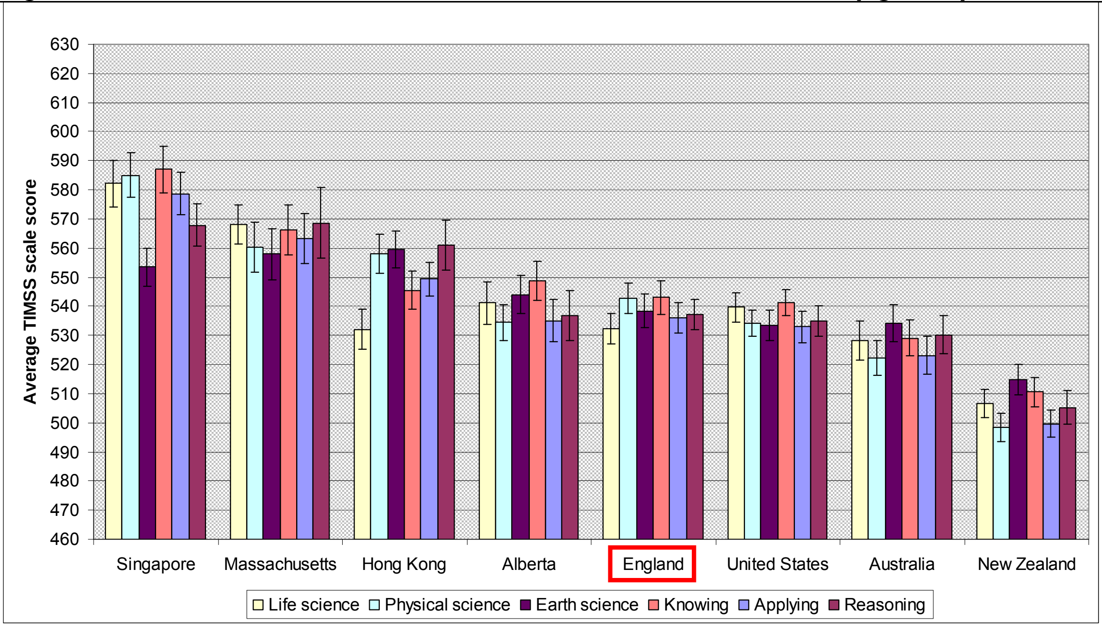
TIMSS 2007 science also divided tasks into the cognitive domains of *knowing*, *applying* and *reasoning.* In science:

- *knowing* means recalling facts and basic procedures;
- *applying* means using models and explaining; and
- *reasoning* means analysing, designing and planning.

As can be seen from Figure 2.7, pupils aged 10 in Singapore and Massachusetts scored significantly higher than pupils in England in the domain of *life science*. However, pupils in England achieved a score in this domain that was not significantly different to that achieved by pupils in Australia and Alberta. In the *physical science* domain, pupils in Singapore, Hong Kong and Massachusetts achieved significantly higher scores compared to pupils in England; however England achieved scores that were significantly higher than both Australia and Alberta in this domain. In the domain of *earth science*, once again Hong Kong, Singapore and Massachusetts achieved a score that was significantly higher than that achieved by England; pupils in Alberta and Australia achieved scores that were not significantly different to those achieved by pupils in England.

In tasks relating to the *knowing* domain, pupils in Singapore and Massachusetts scored significantly higher than pupils in England. The scores for pupils in Alberta and Hong Kong did not differ significantly to those for pupils in England, and pupils in England scored significantly higher than pupils in Australia in this domain. In *applying*, the scores for Singapore, Hong Kong and Massachusetts were significantly higher than those of England, while there was no significant difference between England and Alberta. Pupils in England achieved a score that was significantly higher than pupils in Australia for this domain. In *reasoning*, pupils in Hong Kong, Singapore and Massachusetts scored significantly higher compared to pupils in England, while scores for pupils in Alberta and Australia were not significantly different to those for pupils in England.

Figure 2.7: Science attainment for different domains in TIMSS 2007 (aged 10)



Note: Jurisdictions are shown in descending order of average science achievement. Source: http://nces.ed.gov/surveys/international/ide/

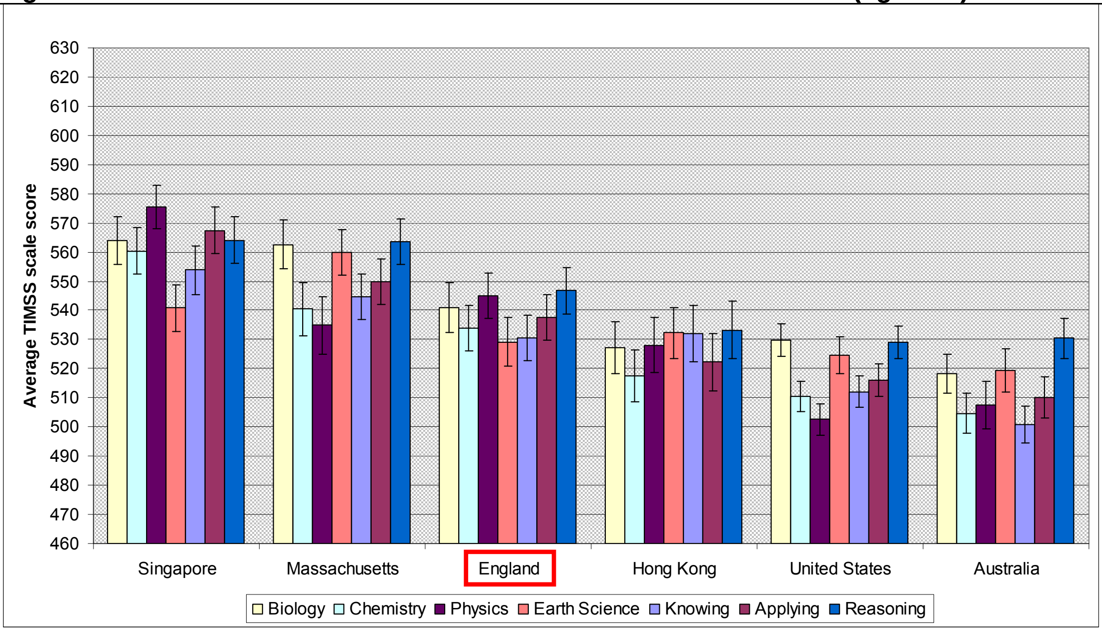
Science at age 14: TIMSS 2007

TIMSS 2007 age 14 science has content domains of *biology*, *chemistry*, *physics* and *earth science* alongside the cognitive domains of *knowing*, *applying* and *reasoning*. *Earth science* includes content that would belong in geography in England.

The data in Figure 2.8 show that pupils in Singapore and Massachusetts scored significantly higher in *biology* compared to pupils in England. However, pupils in England achieved scores that were significantly higher than those for pupils in Australia in this domain. In *chemistry* and *physics*, only pupils in Singapore scored significantly higher than pupils in England; pupils in Australia and the US achieved scores significantly lower than pupils in England, and pupils in Massachusetts achieved scores that were not significantly different to those achieved by pupils in England. Massachusetts achieved scores that were significantly higher than that of England in *earth science*, while Hong Kong, Singapore and Australia achieved scores that did not differ significantly to those of England.

In tasks that assessed the *knowing* domain, pupils in Singapore achieved scores that were significantly higher than those of pupils in England. However, England achieved a score significantly higher than Australia and the US, and a score that did not differ significantly to that achieved by Hong Kong. Once again, Singapore achieved scores that were significantly higher than England in the *applying* and *reasoning* domains. However, England achieved scores that were significantly higher than both Hong Kong and Australia in these domains.

Figure 2.8: Science attainment for different domains in TIMSS 2007 (aged 14)



Note: Jurisdictions are shown in descending order of average science achievement. Source: http://nces.ed.gov/surveys/international/ide/

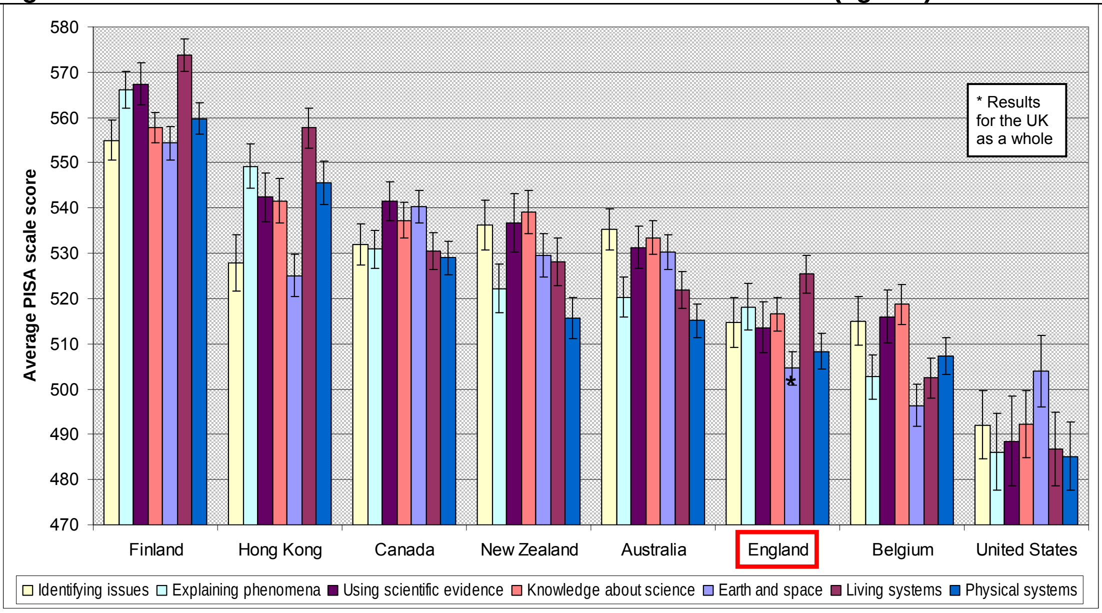
Science at age 15: PISA 2006

In PISA 2006, the content domains were *knowledge about science*, *earth and space*, *living systems*, and *physical systems* while the cognitive domains were *identifying scientific issues*, *explaining phenomena*, and *using scientific evidence*. The OECD did not publish separate scores on these knowledge sub-domains for England, so the following analysis uses UK scores as a proxy.

As can be seen in Figure 2.9, in the *knowledge about science* and *earth and space* domains, Hong Kong, Canada and Australia achieved scores that were higher than the UK at a statistically significant level. For *physical systems*, Hong Kong and Canada achieved scores higher than those achieved by the UK while for living systems, Hong Kong scores higher than those achieved by the UK

In *identifying scientific issues* and *using scientific evidence*, Hong Kong, Canada and Australia achieved scores that were higher than the UK at a statistically significant level. In *explaining phenomena*, pupils in Hong Kong and Canada scored significantly higher than pupils in the UK. Finland was the highest-performing jurisdiction across all domains.

Figure 2.9: Science attainment for different domains in PISA 2996 (age 15)



Note: Jurisdictions are shown in descending order of average science achievement. Source: http://nces.ed.gov/surveys/international/ide/

Section 3 – Curriculum comparisons for English

3.1 Introduction

This section sets out the selection of five comparator jurisdictions based on the findings of the international comparison studies, followed by the initial findings from the analysis of the statutory English curricula of these jurisdictions and England's National Curriculum. The Anglophone jurisdictions are: Alberta, Canada; Massachusetts, USA; New South Wales, Australia; New Zealand; and Singapore[38].

Anglophone jurisdictions have been selected for the main curriculum analysis for two reasons:

- Fairer comparisons can be made between jurisdictions where English is the first or main language;
- Compared to other languages the English language has a relatively irregular written form, including a complex orthography (*i.e.* an unclear relationship between sounds and spellings).

The analysis was also extended to some non-Anglophone jurisdictions, in order to assess how different jurisdictions define expectations around the reading of literature in their curricula.

The purpose of comparing the curricula has been to identify whether there are any similarities and differences between the statutory curricula, which could be used to inform the development of the National Curriculum in England. The content analysis focuses on the level of the statutory curricula for English in high-performing jurisdictions compared to the 1999 and 2007 National Curricula for England. As stated in Section 1.3, the analysis does not include wider non-statutory guidance and other related resources. For this reason, the National Strategies' *Frameworks for teaching* - non-statutory guidance for the teaching of literacy, introduced by the previous Government - are not within the scope of this analysis.

The focus has been on the organisation, breadth, specificity and, where possible, the level of challenge and sequencing of content within comparable age-phases (see Appendix A for more detail). The analysis examines the aims and domains common to the English curricula in the different jurisdictions. A number of examples are provided that illustrate where England's curriculum is less challenging or less specific than the statutory curricula of high-performing jurisdictions.

3.2 Key findings

- The curricula for English across jurisdictions examined are organised very differently, although a structure based on the four modes of speaking,

[38]Although English is not the mother-tongue of most inhabitants of Singapore, it is the official medium of instruction in schools. See http://www.contactsingapore.org.sg/investors/live/language/

listening, reading and writing is the most common.

- Differences in the level of challenge across domains and sub-domains were particularly difficult to assess, in part because of the variety in the structure and level of specificity of each curriculum, and in part because of the non-linear nature of the subject. It is evident that the degree of specificity is not a clear indicator of the level of challenge and also evident that increasing the level of challenge for older pupils is difficult to achieve without also increasing the level of specificity.

- Specificity varies amongst jurisdictions and between the domains and sub-domains within the curricula of those jurisdictions. Alberta has a considerably more detailed curriculum than the others analysed. New South Wales is also very specific, whilst Massachusetts and England 1999 are similar in terms of the level of specificity. England 2007 and New Zealand are both notable for their broader, less detailed statements, New Zealand particularly so.

Reading

- The jurisdictions analysed take a similar approach to *word reading* during the primary years, focusing on securing knowledge of grapheme-phoneme correspondences to decode words. This is commonly expected alongside other word reading strategies.

- The breadth and specificity of *comprehension* is broadly similar across the jurisdictions, although England has a greater emphasis on the *author's craft* in literature. Alberta, Singapore and Massachusetts have a greater focus on *reading for research* than the other curricula analysed.

- There is significant variation in the specification of literature. Three of the six Anglophone jurisdictions analysed (England, Alberta and Massachusetts) and eight European jurisdictions (Denmark, Estonia, France, Latvia, Lithuania, Malta, Portugal and Poland) provide guidance on reading material as part of the curriculum, which is set out by author, by title or by both author and title.

Writing

- *Composition* has approximately the same prominence and level of detail in each of the jurisdictions, but the emphasis on the different skills needed for composition varies greatly.

- *Planning, evaluating, editing* and *proof-reading* are covered very differently across the jurisdictions, with New Zealand and Singapore having less detail than the other curricula.

- There is considerable variation in content and some variation in challenge with regard to *grammar, punctuation* and *spelling*. The Singapore and Massachusetts curricula set out *grammar* requirements in the greatest

Speaking and listening

- *Speaking* and *listening* are represented either as separate domains in English (England, New Zealand, New South Wales primary) or integrated within other domains such as *language* (Massachusetts) or wider all-encompassing domains (Alberta, Singapore and New South Wales secondary).

- Alongside England, Alberta and New South Wales have the greatest breadth of content for *speaking* and *listening* than in other jurisdictions. Singapore also gives prominence to *speaking* and *listening* but is the least specified of the curricula examined at secondary.

- At primary, *speaking* and *listening* relates to a wide range of activity including: developing vocabulary, effective participation in discussion, oral presentation and asking and answering questions. At secondary, *speaking* and *listening* mainly relates to presenting complex information to a range of audiences, debating, adapting presentations for different audiences and processing complex information.

3.3 Selecting comparator jurisdictions

The curriculum analysis first involved the selection of a small number of high-performing jurisdictions in *reading* to benchmark against England. Identifying comparator jurisdictions was in part based on a synthesis of the results from these international comparisons and also on whether an education system for the given jurisdiction is organised at a national or sub-national (state, province, region) level. Given this, it was sometimes necessary to draw on other studies to identify regions with the highest performing pupils within a particular nation. The jurisdictions covered in each survey are set out in Table 3.1.

Table 3.1: Jurisdictions covered in recent waves of PISA and PIRLS studies

		Australia	Alberta	Flemish Belgium	Finland	Hong Kong	Massachusetts	New Zealand	Singapore
Reading	PIRLS 2006 *age 10*		☑	☑		☑	☑ (USA)	☑	☑
	PISA 2009 *age 15*	☑	☑ (Can.)	☑ (Belg.)	☑	☑	☑ (USA)		☑

The PIRLS 2006 assessments were administered in 45 jurisdictions in total, including two language communities within Belgium (French and Flemish), and five provinces within Canada. The sample size was approximately 220,000 pupils[39]. The mean age of participants was 10.5, with a minimum age of 9.5 years. The three top performing education systems in the 2006 PIRLS study were the Russian Federation (565), Hong Kong (564) and Alberta, Canada (560). England had an average score of 539, which was significantly above the scale[40] average of 500[41].

The main focus of the PISA 2009 age 15 assessments was reading. Results from the assessment reported the highest reading score for Shanghai[42] (556), followed by Korea (539) and Finland (536)[43]. England achieved a mean reading score of 495, which was not statistically significantly different from the OECD average score of 493[44].

Massachusetts did not participate in the PISA 2009 or PIRLS 2006 reading assessments; however, it did perform very strongly within the US on NAEP national reading assessments[45].

Among all the jurisdictions taking part in the above studies, it is possible to identify five Anglophone jurisdictions with the highest achieving pupils in reading. The selected jurisdictions are:

- Alberta;
- Massachusetts;
- New South Wales;
- New Zealand; and
- Singapore.

3.4 Curriculum analysis for English - an overview

The curriculum documents analysed are those that were being taught in schools prior to and at the time of the PISA and PIRLS assessments. The 2007 National Curriculum for England has also been reviewed to understand how the curricula of high-performing jurisdictions compare with the curriculum

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[39] Joncas, M. (2007). *PIRLS 2006 Sampling Weights and Participation Rates*. In Martin, M.O. Mullis, I.V.S. and Kennedy, A.M. (eds.) (2007). *PIRLS 2006 Technical Report*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[40] The supporting metric for the PIRLS 2006 scale was established by setting the average of the mean scores for participants in PIRLS 2001 at 500, with a standard deviation of 100. Foy, P. Galia, J. and Li, I. (2007). *Scaling the PIRLS 2006 Reading Assessment Data*. In Martin, M.O. Mullis, I.V.S. and Kennedy, A.M. (eds.) (2007). *PIRLS 2006 Technical Report*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[41] Mullis, I.V.S. Martin, M.O. Kennedy, A.M. and Foy, P. (2007). *PIRLS 2006 International Report: IEA's Progress in International Reading Literacy Study in Primary Schools in 40 Countries*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[42] Pupil scores in PISA 2009 were scaled to fit the metric for pupil scores in PISA 2000 in order to facilitate comparisons between years. Scores for PISA 2000 were normally distributed with a mean of 500 and a standard deviation of 100. See *PISA 2009 Study: How big is the gap? A comparison of pupil attainment in England with the top-performing countries (2011).* DfE Research Report DFE-RR149.
[43] OECD (2010a). *PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I).* Paris: OECD Publishing.
[44] Bradshaw, J. Ager, R. Burge, B. and Wheater, R. (2010). *PISA 2009: Achievement of 15-Year-Olds in England*. Slough: NFER.
[45] National Center for Education Statistics (2011). *The Nation's Report Card: Reading 2011* (NCES 2012–457). Washington DC: Institute of Education Sciences, US Department of Education

currently being taught in England's secondary schools.

Comparing the curriculum documents for the six jurisdictions revealed significant variation in how English subject curricula are organised (see Appendix A - Table A1). Massachusetts, Singapore and New South Wales are organised into two-year groupings; New Zealand organised into outcome levels approximating to two years per level; England set out in key stages; and Alberta is set out year by year.

With the exception of Alberta, the curricula are clearly organised into domains that broadly align with the four modes of communication: *speaking, listening, reading* and *writing*, although the terms used to describe these modes differ between jurisdictions.

It is worth noting that more recent curriculum reforms also show no tendency towards one favoured model: New Zealand is moving away from a curriculum organised around the three domains of *speaking and listening*, *reading* and *writing*; whilst the others remain fairly similar. Table 3.2 sets out how curricula analysed for this report are organised and any changes as a result of recent reforms.

Table 3.2: Organisation of English curricula

	Organisation of curriculum analysed for this report	Organisation of latest or forthcoming curriculum
New South Wales	**2007[46] (Years 1 to 7):** • Talking & listening • Reading • Writing **2003 (Years 8 to10):** Through responding to and composing a wide range of texts in context and through close study of texts, students will develop skills, knowledge and understanding in order to: • speak, listen, read, write, view and represent • use language and communicate appropriately and effectively • think in ways that are imaginative, interpretive and critical • express themselves and their relationships with others and the world • learn and reflect on their learning through their study of English.	**Adopts federal curriculum from 2014:** • Speaking and listening • Reading and viewing • Writing and representing
Alberta	**2000:** Students will listen, speak, read, write, view and represent to: • explore thoughts, ideas, feelings and experiences • comprehend and respond critically to oral, print and other media texts • manage ideas and information • enhance the clarity and artistry of communication • respect, support and collaborate with others	n/a
New Zealand	**1994:** • Oral language • Written language • Visual language	**2010:** • Listening, reading, and viewing • Speaking, writing, and presenting
Singapore	**2001:** • Language for information • Language for literary response and expression • Language for social interaction	**2010:** • Listening and viewing • Reading and viewing • Speaking and representing • Writing and representing • Grammar • Vocabulary
Massachusetts	**2001:** • Language • Reading and literature • Composition • Media	**2011:** • Reading • Writing • Speaking and listening
England	**1999:** • Speaking and listening • Reading • Writing	**2007 (secondary):** • Speaking and listening • Reading • Writing

[46] The 1998 New South Wales K-6 syllabus was re-published in 2007 to include foundation statements for each stage

Breadth

As highlighted by Ruddock and Sainsbury[47], it is difficult to compare the breath of content coverage across English curricula due to a number of factors which are detailed elsewhere in this report but outlined briefly here. Firstly, the level of specificity varies widely between jurisdictions. Secondly there is a general tendency for specificity to decrease in the secondary phase. Lastly, there is no common layout of content, either in terms of the structure of domains and sub-domains, or the sequencing of content into age phases or levels.

As set out in Table 3.2, each jurisdiction covers the domains of reading, writing, speaking and listening, giving each domain significant weight from Years 1 to 11. There are, however, differences in the breath of coverage across jurisdictions:

- *Word reading* is covered in each curriculum, with significant prominence and breadth during early primary. This focuses on securing decoding skills, with some variations in the specification of strategies to be taught alongside the use of phonics. The breadth of study varies considerably between jurisdictions for *reading comprehension*, with differences occurring in the more specific or sophisticated textual comprehension approaches taken by England (1999) and Alberta.

- All curricula specify the *reading of literary and non-literary texts*, with the majority outlining the range of specific text types or genres for study. England, for example, sets out the range of literary and non-fiction texts in the *breadth of study*, while Singapore specifies types of text under its three main curriculum headings. Differences in coverage of reading are particularly apparent in the specification of *reading for information and research*, where Alberta, Singapore and Massachusetts are the most comprehensive.

All curricula specify the *composition of fiction, non-fiction and poetic writing*, but differ in whether they set out specific types of text as, for example, set out in the *breadth of study* for England (e.g. stories, poems, playscripts, autobiographies, screenplays, diaries). There is significant variation in the amount of coverage for *planning, evaluating, editing and proof reading* amongst curricula, ranging from considerable coverage (Alberta) to very little (Singapore). The amount of content for *grammar* also varies significantly at both primary and secondary. Other than New Zealand which has no discernable detail, the other curricula cover the similar grammar fundamentals, except for Singapore, which covers significantly more grammar than the other jurisdictions.

The coverage of *speaking and listening* also varies, having a greater breath of content in the Alberta and New South Wales curricula than in other

[47] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries*. DCSF Research Report DCSF-RW048.

jurisdictions.

Specificity

The level of specificity varies considerably amongst the curricula analysed. The analysis has shown that the degree of specificity depends on three factors: the detail provided for each learning outcome; the amount of content that is repeated from earlier stages; and the use of teaching examples.

Alberta stands out as having the most detailed curriculum, with very specific learning statements set out year by year across five inter-related *general outcomes*. The New South Wales primary curriculum has a high level of specificity, separating the headline domains into *learning to* and *learning about,* which are then divided into further sub-domains. New South Wales has slightly less content in its secondary curriculum than it does for primary.

Massachusetts has a level of specificity akin to England 1999 and Singapore. The Massachusetts curriculum has examples of classroom practice after many of the outcome statements. Massachusetts and Singapore stand out in having a separate and detailed *grammar* sections. However, Singapore has less detail in *planning* and in *editing writing* than many of the other jurisdictions examined.

The statements in the 2007 secondary National Curriculum for England are fairly unspecific by comparison, although there are more supporting guidance notes within the document than found in other curricula. The New Zealand curriculum is set out as very broad attainment levels, with very few statements per level. The impact of this is that there is very little information for teachers on, for example, what strategies should be used to teach pupils to decode or how to write for specific purposes.

Across all of the curricula analysed, the greatest variation in level of specificity is found in the primary phase. There is a tendency for *all* curricula to become less specific for the secondary phase.

Challenge

Differences in the level of challenge across domains and sub-domains were particularly difficult to assess, in part because of the variety in the structure and level of specificity of each curriculum, and in part because of the non-linear nature of the subject. The level of challenge in English is related more to expected outcomes than to the particular concepts. This means that the level of challenge cannot easily be judged from curriculum documents alone. For example, it is difficult to judge the level of challenge in reading without a specification of the texts to be read in each year or over longer age phases. Similarly, the level of challenge for writing is also dependent on the complexity of the task, as well as the attention to language conventions and meeting the needs of the reader. Grammar, and to a lesser extent spelling, have been the two areas where it has been easier to make direct comparisons about levels of challenge.

It has also been evident from the analysis that the degree of specificity is not a clear indicator of the level of challenge and that increasing the level of challenge for older pupils is difficult to achieve without also increasing the level of specificity. Alberta appears more challenging overall than the other curricula at Years 10 and 11, although in part this may be due to the degree to which the process of *analysing, interpreting and composing text* is broken down within the curriculum.

3.5 Curriculum aims

All the curriculum documents examined begin by explaining the importance of English, both as a curriculum subject and for personal development. The value of language development as a first principle of English is outlined in all the jurisdictions' curriculum documentation, for example:

- **New Zealand:** "*Language development is essential to intellectual growth. It enables us to make sense of the world around us. The ability to use spoken and written language effectively, to read and to listen and to discern critically messages* […] *is fundamental to both learning and to effective participation in society and the workforce.*"[48]

- **Alberta:** "*The ability to use language effectively enhances student opportunities to experience personal satisfaction and to become responsible, contributing citizens and lifelong learners*"[49] and *"As well as being a defining feature of culture, language is an unmistakable mark of personal identity and is essential for forming interpersonal relationships, extending experiences, reflecting on thought and action, and contributing to society"* [50].

- **New South Wales:** "*Language is central to students' intellectual, social and emotional development and has an essential role in all key learning areas. The learning experiences provided in this syllabus will assist students to become competent in English and to use language effectively in a range of contexts*"[51] and *"Competence in English will enable students to learn about the role of language in their own lives, and in their own and other cultures. They will then be able to communicate their thoughts and feelings, to participate in society, to make informed decisions about personal and social issues, to analyse information and viewpoints, to use their imaginations and to think about the influence of culture on the meanings made with language"* [52].

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[48] New Zealand Ministry of Education (1994). *English in the New Zealand Curriculum* http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/Schools/EnglishInTheNewZealandCurriculum.pdf
[49] Alberta Learning (2000) *English Language Arts* (p1) http://education.alberta.ca/media/450519/elak-9.pdf
[50] Alberta Learning (2000) *English Language Arts* (p1) http://education.alberta.ca/media/450519/elak-9.pdf
[51] New South Wales Department of Education (2007) *English K-6 Syllabus* (p6) http://k6.boardofstudies.nsw.edu.au/files/english/k6_english_syl.pdf
[52] New South Wales Department of Education (2007) *English K-6 Syllabus* (p6) http://k6.boardofstudies.nsw.edu.au/files/english/k6_english_syl.pdf

Beyond these high-level statements, all the curricula analysed have curriculum aims for English (see Table A1, Appendix A). These are set out in different ways, including very detailed statements (e.g. Massachusetts), long narratives explaining the significance the domains (e.g. Alberta), and principles underpinning the teaching of the subject (e.g. Singapore). Broadly, the curricula emphasise similar priorities and principles around the importance of language, effective written and spoken communication, the value of literature, and the impact of proficient language use on the individual and society.

Taken together, the aims across all the comparator curricula can be articulated as follows:

- From early primary, securing development of word reading skills quickly, whilst pupils learn to enjoy and understand books that they hear read to them;
- Spelling, punctuating and using grammar accurately as part of writing clearly, confidently and imaginatively;
- Reading widely and enjoying reading; developing curiosity, understanding and critical appreciation of the world through texts read;
- Developing confidence, independence and a personal style through proficient and accurate use of language;
- Engaging with history, society and literary heritage through the study of literature from different periods and cultures and of different genres;
- Communicating effectively through writing, debate, discussion and presentation and using language conventions; and
- Understanding language conventions and developing a rich vocabulary.

In terms of a cross-curricular approach to language and literacy, amongst the Anglophone jurisdictions analysed, only England specifies a set of overarching aims that includes the English language. Alberta and Singapore both have separate documents that set out their vision for education but these make no reference to language[53] [54]. The handbook for the England National Curriculum 1999[55] makes explicit reference to the importance of English across the curriculum in the key skill of *communication* embedded across all subjects. The foreword states:

[53] Government of Alberta (2011) *Guide to Education: ECS to Grade 12* http://education.alberta.ca/media/6542444/guidetoed_2011-2012.pdf
[54] Ministry of Education Singapore (2009) *Desired Outcomes of Education* (p1) http://www.moe.gov.sg/education/desired-outcomes/
[55] Department for Education and Employment and Qualifications and Curriculum Authority (1999) *English : The National Curriculum for England Key stages 1-4* http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/English%201999%20programme%20of%20study_tcm8-12054.pdf

"The focus of this National Curriculum, together with the wider school curriculum, is therefore to ensure that pupils develop from an early age the essential literacy and numeracy skills they need to learn…"

3.6 Domains

The variety amongst the curricula makes an assessment of coverage difficult, as reported by Ruddock and Sainsbury[56] for primary curricula. By analysing the detailed content, however, it has been possible to identify common domains and sub-domains[57] which capture all the key elements of the curriculum. These are:

- Reading
  - Reading strategies
  - Comprehension
  - Literature
  - Research
- Writing
  - Planning writing
  - Composition
  - Evaluating, editing and proof-reading
  - Grammar, spelling and punctuation.
- Speaking and listening

With these domains and sub-domains, it has been possible to assess coverage and identify the extent to which there is commonality or variation across the curricula analysed.

Reading

Our analysis found that *reading* is broadly split into four areas across the curricula which cover:

- ***Reading strategies***: the skills and strategies needed to decode the written word and to have a literal comprehension at the word and sentence level.
- ***Comprehension***: once word reading skills have been acquired, *comprehension* relates to the skills and strategies needed for understanding and analysing the meaning and nuances of whole texts. It also relates to understanding the impact of language and structure and developing personal preferences.
- ***Literature***: the range of literary works (e.g. novels, plays, short stories, and poems) that pupils are expected to read and study.

[56] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries*. DCSF Research Report DCSF-RW048.
[57] Handwriting and English language variation were also domains common to all jurisdictions and have been included in the summary analysis in the Tables A3 and A4 at Appendix A, but not referenced in this analysis summary.

- ***Research***: the range of strategies needed to search for information and to summarise and analyse the results of such research.

Reading strategies
All the curricula analysed were developed before systematic phonics teaching in early reading had such a high national and international profile. Table A2 (Appendix A) maps content in this area in more detail.

One of the most well-known studies into the impact of phonics was the 2006 United States National Reading Panel report[58]. It found that "*this type of phonics instruction (i.e. systematic synthetic phonics) benefits both students with learning disabilities and low-achieving students who are not disabled*", going on to observe that such teaching "*was significantly more effective in improving low socio-economic status (SES) children's alphabetic knowledge and word reading skills than instructional approaches that were less focused on these initial reading skills*". Systematic phonics teaching also benefited the spelling ability of good readers.

An Australian study, published a year earlier, found similarly[59]: *"The incontrovertible finding from the extensive body of local and international evidence-based literacy research is that for children during the early years of schooling (and subsequently if needed) to be able to link their knowledge of spoken language to their knowledge of written language, they must first master the alphabetic code.*" The study referred to the need to teach this knowledge "*explicitly, systematically, early and well*".

In the UK, the Clackmannanshire study in Scotland[60], the Rose Review of early reading[61] and various reports by Ofsted, especially *Reading by six* in 2010[62], all furnished additional, similar evidence. Ofsted reported that *"the best primary schools in England teach virtually every child to read"* and that in the twelve successful schools visited for the 2010 report "*the diligent, concentrated and systematic teaching of phonics*" was central to the success of the schools that were achieving high standards in reading by the end of Year 2.

Prior to the prevalence of systematic phonics, the teaching of reading drew heavily on a view that pupils should be taught to use a combination of approaches, sometimes referred to as 'cueing systems' or 'strategies', to make sense of what they were reading. All of the curricula analysed specify this combination of approaches, requiring pupils to use phonological knowledge (the sounds of spoken language), grammatical knowledge, visual

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[58] The US National Reading Panel (2006). R*eport of the National Reading Panel: Teaching Children to Read.* http://www.nichd.nih.gov/publications/nrp/findings.cfm
[59] Australian Government, Department of Education, Science and Training (2005). *Teaching Reading.* http://www.dest.gov.au/nitl/documents/report_recommendations.pdf
[60] Scottish Executive, Education Department (2005). *A Seven Year Study of the Effects of Synthetic Phonics Teaching on Reading and Spelling Attainment.* http://www.scotland.gov.uk/Resource/Doc/933/0044071.pdf
[61] Rose, J (2006). *Independent review of the teaching of early reading: final report*. DfES report (0201-2006DOC-EN) http://media.education.gov.uk/assets/files/pdf/i/independent%20review.pdf
[62] Ofsted (2010). *Reading by Six: how the best schools do it.* Manchester: Ofsted

cues, and semantic cues to make sense of the written word. For example, the New Zealand curriculum states:

> "*The [reading] process includes using semantics, syntax, visual cues, context, and background knowledge, and combining these to construct meaning. Dame Marie Clay says of the reading development of children that they continue 'to gain in this complex processing throughout their formal education…*"[63],

Similarly the Alberta curriculum states that:

> *"Students use a variety of strategies and cueing systems as they interact with oral, print and other media texts*"[64].

The extracts from England 1999 and New South Wales in Table 3.3 exemplify the similarities in approach between the jurisdictions:

Table 3.3: Example of reading strategies in England (1999) and New South Wales (2007)

England 1999 – Years 1 and 2	New South Wales 2007 Stage 1 - Year 2
Reading strategies Pupils should be taught to read with fluency, accuracy, understanding and enjoyment: **Word recognition and graphic knowledge** They should be taught phonemic awareness and phonic knowledge to decode and encode words, including to: • hear, identify, segment and blend phonemes in words in the order in which they occur • sound and name the letters of the alphabet • identify syllables in words • recognise that the same sounds may have different spellings and that the same spellings may relate to different sounds • read on sight high-frequency words and other familiar words • recognise words with common spelling patterns • recognise specific parts of words, including prefixes, suffixes, inflectional endings, plurals • link sound and letter patterns, exploring rhyme, alliteration and other sound patterns	**Draws on an increasing range of skills and strategies when reading and comprehending texts** **Graphological and phonological information** • recognises upper-case letters • automatically recognises irregular words such as 'come', 'are', 'laugh' • exchanges sounds–letters to make a new word • blends words ending and beginning with double consonants and consonant digraphs to work out unknown words • blends long vowel sounds with consonants and consonant blends • blends 'consonant-vowel-vowel-consonant' (cvvc) words, words with vowel digraphs (e.g. 'rain – train'), double vowel sounds (e.g. 'ee') and other common digraphs (e.g. 'ar', 'ay') • draws on knowledge of letter–sound relationships when trying to read unknown words, e.g. sounds out, attempts to break words into syllables • responds to punctuation when reading aloud, e.g. full stop, question mark, comma, exclamation mark, contractions.

In addition to the word reading strategies and contextual understanding common to both the England and New South Wales curricula, New South Wales requires pupils to be taught about and to recognise specific

[63] New Zealand Ministry of Education (1994). *English in the New Zealand Curriculum.* (p141) http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/Schools/EnglishInTheNewZealandCurriculum.pdf
[64] Alberta Learning (2000) *English Language Arts.* http://education.alberta.ca/media/450519/elak-9.pdf (p17)

grammatical details in order to aid understanding of the text. Grammatical understanding in the England National Curriculum, on the other hand, is limited to word order and whole text structure. This is shown in the extracts from the curriculum documents in Table 3.4 below.

Table 3.4: Example of grammar and reading strategies in England (1999) and New South Wales (2007)

England 1999 – Years 1 and 2	New South Wales 2007 Stage 1 - Year 2
To read with fluency, accuracy, understanding and enjoyment, pupils should be taught to use a range of strategies to make sense of what they read. **Grammatical awareness** They should be taught to use grammatical understanding and their knowledge of the content and context of texts to: • understand how word order affects meaning • decipher new words, and confirm or check meaning • work out the sense of a sentence by re-reading or reading ahead **Contextual understanding** • focus on meaning derived from the text as a whole • use their knowledge of book conventions, structure, sequence and presentational devices • draw on their background knowledge and understanding of the content	Draws on an increasing range of skills and strategies when reading and comprehending texts. **Grammatical Information** • identifies a clause in printed texts • identifies a sentence in printed texts • identifies words in texts which have similar meaning • recognises nouns and noun groups and pronouns in printed texts • identifies noun–pronoun, subject–verb links in written texts • identifies words that indicate where, why, when and how actions take place • identifies conjunctions in printed texts

Comprehension

There is significant variation in the specificity of reading comprehension across jurisdictions, as shown in the map of content in Table A2 (Appendix A).

During early primary, to demonstrate their understanding of texts read for themselves and heard read aloud, the common requirement is for pupils to re-tell or recall facts from an information text or a story, and to discuss the key features. In comparison to the other jurisdictions, Massachusetts and Alberta appear to be more challenging in early primary. In Alberta, pupils in Year 1 are expected to analyse text structure, relate their personal experiences to their reading and develop their own preferences for reading material. Massachusetts also sets out a high level of challenge at this stage, requiring pupils to identify similarities in plot, setting and character among the works of an author or illustrator.

In the secondary phase, breadth and challenge increase through widening the range of texts that pupils are expected to read and study. Each jurisdiction requires pupils to use an increasingly sophisticated range of skills and techniques to analyse text content and features. The Massachusetts curriculum is more detailed than the National Curriculum and sets out basic expectations for *understanding a text*, with further, more specific expectations set out for *making connections, genre, theme* across fiction, non-fiction and poetry. The analysis and interpretation of texts at Years 10 and 11 of the

Alberta curriculum is broken down into significant detail, thus making the different elements of comprehension appear more challenging than the other curricula.

Our analysis of approaches to reading comprehension supports other recent findings that, at primary and lower secondary, The National Curriculum focuses more on the intentions and choices of the author, whereas other curricula focus more on understanding what has been read[65 66]. Table 3.5 illustrates this difference between England and Singapore.

Table 3.5: Example of reading comprehension in England (1999) and Singapore (2001)

England 1999 – Years 7 to 11	Singapore 2001 –Year 9

Understanding texts
 	
To develop understanding and appreciation of texts, pupils should be taught:
 	
Reading for meaning
 	
Understanding the author's craft
 	
• how language is used in imaginative, original and diverse ways
• to reflect on the writer's presentation of ideas and issues, the motivation and behaviour of characters, the development of plot and the overall impact of a text
• to distinguish between the attitudes and assumptions of characters and those of the author
• how techniques, structure, forms and styles vary
• to compare texts, looking at style, theme and language, and identifying connections and contrasts.
	Listen to/read/view a variety of texts and demonstrate understanding of content in oral or written form
	• Make predictions about storyline / content, characters using
	  ◦ contextual clues
	  ◦ prior knowledge
	• Identify gist / main idea(s) through looking at characters, events, setting, plot
	• Recall details about characters, events, setting, plot
	• Infer and draw conclusions about characters, their actions and motives, events, setting
	• Infer meaning using
	  ◦ contextual clues
	  ◦ prior knowledge
	  ◦ knowledge of familiar cultures in Singapore, Asia and the rest of the world
	
	Listen to/ read/ view a variety of texts and demonstrate in oral or written form the ability to acquire and use knowledge for a variety of purposes
	
	• Give reasons to support a response / point of view / an opinion
	• Organise and summarise information: list, sequence, compare, contrast, classify information
	• Evaluate texts for reasonableness of ideas and persuasive language
	• Explore possible factors relating to motives of characters / events in a story: causes, consequences, reasons
	• Abstract ideas / themes from a text

Reading literature

The *reading and study of literature* are features of all the curricula analysed, with *non-fiction reading* also set out in some. The organisation of reading lists varies with no common model; they may be set out by author, by title or by both author and title. This variety is apparent in the specification of literature within the original six Anglophone jurisdictions considered (see Appendix A -

[65] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.

[66] Ofsted (2009) *English at the Crossroads: An Evaluation of English in Primary and Secondary Schools 2005/08.* London: Ofsted

Table A2) and also among the non-Anglophone jurisdictions with high-performing or improving reading scores in international comparisons (see Eurydice 2011[67]).

Among the comparator Anglophone jurisdictions, England, Alberta and Massachusetts all specify literature as part of their curriculum. Among the non-Anglophone jurisdictions, eight European jurisdictions (Denmark, Estonia, France, Latvia, Lithuania, Malta, Portugal and Poland) also provide lists of texts or authors. The analysis also showed that curricula with no specified reading lists commonly specify the genres of works to be read. While fiction is at the core of all lists, some also include non-fiction works while England, Massachusetts and Poland also list poets and playwrights.

Almost all of the reading lists reviewed took the form of guidance or exemplars, with teachers given the autonomy to select particular texts. Although reading lists, where provided, are expected to form the basis of study, each jurisdiction appears to give schools or teachers the flexibility to make judgements about the suitability of the texts listed, and the option to choose alternatives. Most jurisdictions set out their reading lists for both primary and secondary with the exception of England which is secondary only.

The only jurisdictions with a statutory requirement to read specific titles or the works of a particular author were Denmark and England. In Denmark, the requirement relates to the works of 15 Danish authors while in England the only required author is Shakespeare during the secondary phase.

These requirements in England and Denmark exemplify a more common purpose of the reading lists analysed, namely to ensure that pupils have access to a national literary heritage. The reading lists of the curricula analysed often set out national literature separately; for example, Alberta uses an icon to indicate Canadian texts.

Most jurisdictions with reading lists provided these banded into age-phases of more than one year, with teachers given the freedom to decide on the most appropriate texts, except for the Alberta curriculum which recommends texts of increasing complexity each year.

The following sections exemplify in more detail how each of the jurisdictions considered sets out reading lists.

England (1999) and (2007)

In the England (1999) curriculum, the *breadth of study* stipulates the ranges of literature, non-fiction and non-literary texts that should be included as part of the curriculum (see Table 3.6a). At secondary, there is a requirement for pupils to study two plays by Shakespeare, plus two major writers and four major poets published before 1914, from a specified list; exemplar authors are

[67] Eurydice (2011). *Teaching Reading in Europe: Contexts, Policies and Practices*. http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/130EN.pdf

provided for other genres.

England's current secondary curriculum (2007), provides a list of authors, playwrights and poets which are categorised into: *contemporary writers*; *authors from the English literary heritage;* and *authors from different cultures and traditions* (see Table 3.6b)*.* Two plays by Shakespeare is the only statutory requirement.

Table 3.6a: Example of the reading list in the National Curriculum (1999)

	Range of texts
Years 1-2	**Literature** • stories and poems with familiar settings and those based on imaginary or fantasy worlds • stories, plays and poems by significant children's authors • retelling of traditional folk and fairy stories • stories and poems from a range of cultures • stories, plays and poems with patterned and predictable language • stories and poems that are challenging in terms of length of vocabulary • texts where the use of language benefits from being read aloud and reread **Non-fiction and non-literary** • print and ICT-based information texts, including those with continuous texts and relevant illustrations • dictionaries, encyclopaedias and other reference materials
Years 3-6	**Literature** • a range of modern fiction by significant children's authors • long established children's fiction • a range of good-quality modern poetry • classic poetry • texts drawn from a variety of cultures and traditions • myths, legends and traditional stories • playscripts **Non-fiction and non-literary** • diaries, autobiographies, biographies, letters • print and ICT-based reference and information materials • newspapers, magazines, articles, leaflets, brochures, advertisments.
Years 7-11	**Literature** • plays, novels, short stories and poetry from the English literary heritage, including: i. two plays by Shakespeare, one of which should be studies in Years 7-9 ii. a drama by major playwrights, with the following examples: *William Congreve, Oliver Goldsmith, Christopher Marlowe, Sean O'Casey, Harold Pinter, J B Priestly, Peter Shaffer, GB Shaw, R B Sheridan, Oscar Wilde.* iii. works of fiction by two major writers published before 1914, selected from the following list: *Jane Austen, Charlotte Bronte, Emily Bronte, John Bunyan, Wilkie Collins, Joseph Conrad, Daniel Defoe, Charles Dickens, Arthur Conan Doyle, George Eliot, Henry Fielding, Elizabeth Gaskell, Thomas Hardy, Henry James, Mary Shelley, Robert Louis Stevenson, Jonathan Swift, Anthony Trollope, H G Wells* iv. two works of fiction by major writers published after 1914, with the following examples: *E M Forster, William Golding, Graham Greene, Aldous Huxley, James Joyce, DH Lawrence, Katherine Mansfield, George Orwell, Muriel Spark, William Tervor, Evelyn Waugh.* v. poetry by four major poets published before 1914, selected from the following list: *Matthew Arnold, Elizabeth Barrett Browning, William Blake, Emily Bronte, Robert Browning, Robert Burns, Lord Byron, Geoffrey Chaucer, John Clare, Samuel Taylor Coleridge, John Donne, John Dryden, Thomas Gray, George Herbert, Robert Herrick, Gerard Manley Hopkins, John Keats, Andrew Marvell, John Milton, Alexander Pope, Christina Rossetti, William Shakespeare (sonnets), Percy Bysshe Shelley, Edmund Spenser, Alfred Lord Tennyson, Henry Vaughan, William Wordsworth, Sir John Wyatt* vi. poetry by four major poets published after 1914, with the following examples : *W H Auden, Gillian Clarke, Keith Douglas, T S Eliot, U A Fanthorpe, Thomas Hardy, Seamus Heaney, Ted Hughes, Elizabeth Jennings, Philip Larkin, Wilfred Owen, Sylvia Plath, Stevie Smith, Edward Thomas, R S Thomas, W B Yeats*

	Range of texts
	• recent and contemporary drama, fiction and poetry written for young people and adults, with the following examples: *Drama: Alan Ayckbourn, Samuel Beckett, Alan Bennett, Robert Bolt, Brain Friel, Willis Hall, David Hare, Willie Russell, RC Sherriff, Arnold Wesker* *Fiction: J G Ballard, Berlie Doherty, Susan Hill, Laurie Lee, Joan Lingard, Bill Naughton, Alan Stillitoe, Mildred Taylor, Robert Westall* *Poetry: Simon Armitage, James Berry, Douglas Dunn, Liz Lochead, Adrian Mitchell, Edwin Muir, Grace Nichols, Jo Shapcott* • drama, fiction and poetry by major writers from different cultures and traditions, with the following examples: *Drama: Athol Fugard, Arthur Miller, Wole Soyinka, Tennessee Williams* *Fiction: Chinua Achebe, Maya Angelou, Willa Cather, Anita Desai, Nadine Gordimer, Ernest Hemingway, HH Richardson, Doris Lessing, R K Narayan, John Steinbeck, Ngugi wa Thiong'o* *Poetry: E K Brathwaite, Emily Dickinson, Robert Frost, Robert Lowell, Les Murray, Rabindranath Tagore, Derek Walcott* **Non-fiction and non-literary texts** • Literary non-fiction • Print and ICT-based information and reference texts • Media and moving image text Examples of non-fiction and non-literary texts: *Personal record and viewpoints on society: Peter Ackroyd, James Baldwin, John Berger, James Boswell, Vera Brittain, Lord Byron, William Cobbett, Gerald Durrell, Robert Graves, Samuel Johnson, Laurie Lee, Samuel Pepys, Flora Thompson, Beatrice Webb, Dorothy Wordsworth* *Travel writing: Jan Morris, Freya Stark. Laurens Van Der Post* *Reportage: James Cameron, Winston Churchill, Alistair Cooke, Dilys Powell* *The natural world: David Attenborough, Rachel Carson, Charles Darwin, Steve Jones*

Table 3.6b: Example of the reading list in the Secondary National Curriculum (2007)

	Range of texts
Years 7-9	**Literature** • stories, poetry and drama drawn from different historical times, including contemporary writers. With the following examples of contemporary writers: *Douglas Adams, Richard Adams, David Almond, Simon Armitage, Bernard Ashley, Jean M Auel, Malorie Blackman, Alan Bennett, Henrietta Branford, Charles Causley, Brian Clark, Frank Cottrell Boyce, Berlie Doherty, Carol Ann Duffy, Alan Garner, Alan Gibbons, Morris Gleitzman, Willis Hall, Adrian Henri, Susan Hill, Anthony Horowitz, Janni Howker, Jackie Kay, Elizabeth Laird, Joan Lingard, Roger McGough, Michelle Magorian, Jan Mark, Adrian Mitchell, Michael Morpurgo, Brian Patten, Peter Porter, Philip Pullman, Celia Rees, Philip Reeve, Michael Rosen, Willy Russell, Louis Sachar, Marcus Sedgewick, Dodie Smith, Robert Swindells and Robert Westall.* • texts that enable pupils to understand the appeal and importance over time of texts from the English literary heritage, with the following examples: *WH Auden, Robert Bolt, TS Eliot, Robert Frost, William Golding, Graham Greene, Seamus Heaney, Ted Hughes, Elizabeth Jennings, Philip Larkin, DH Lawrence, Ursula Le Guin, Jack London, George Orwell, Wilfred Owen, Sylvia Plath, Siegfried Sassoon, George Bernard Shaw, RC Sherriff, Dylan Thomas, RS Thomas and John Wyndham* • texts that enable pupils to appreciate the qualities and distinctiveness of texts from different cultures and traditions, with the following examples: *John Agard, Maya Angelou, Kwesi Brew, Anita Desai, Deborah Ellis, Athol Fugard, Jamila Gavin, Nadine Gordimer, Gaye Hicyilmaz, Beverly Naidoo, Grace Nichols, C Everard Palmer, Bali Rai, John Steinbeck, Meera Syal, Mildred D Taylor, Mark Twain, Adeline Yen Mah and Benjamin Zephaniah.* • at least one play by Shakespeare. **Non-fiction and non-literary:** • forms such as journalism, travel writing, essays, reportage, literary non-fiction and multimodal texts including film • purposes such as to instruct, inform, explain, describe, analyse, review, discuss and persuade.

Years 10-11	**Literature** • stories, poetry and drama drawn from different historical times, including contemporary writers. With the following examples of contemporary writers*: Douglas Adams, Richard Adams, Fleur Adcock, Isabel Allende, Simon Armitage, Alan Ayckbourn, JG Ballard, Pat Barker, Alan Bennett, Alan Bleasdale, Bill Bryson, Angela Carter, Bruce Chatwin, Brian Clark, Gillian Clarke, Robert Cormier, Jennifer Donnelly, Keith Douglas, Roddy Doyle, Carol Ann Duffy, UA Fanthorpe, John Fowles, Brian Friel, Mark Haddon, Willis Hall, David Hare, Tony Harrison, Susan Hill, SE Hinton, Jackie Kay, Harper Lee, Laurie Lee, Andrea Levy, Joan Lingard, Penelope Lively, Liz Lochhead, Mal Peet, Peter Porter, Philip Pullman, Willy Russell, Jo Shapcott and Zadie Smith.* • texts that enable students to understand the nature, significance and influence over times of text from the English literary heritage, with the following examples: *Kingsley Amis, WH Auden, TS Eliot, EM Forster, Robert Frost, William Golding, Graham Greene, Seamus Heaney, Ted Hughes, Aldous Huxley, Elizabeth Jennings, James Joyce, Philip Larkin, DH Lawrence, Katherine Mansfield, Sean O'Casey, George Orwell, Wilfred Owen, Harold Pinter, Sylvia Plath, JB Priestley, Siegfried Sassoon, Peter Shaffer, George Bernard Shaw, RC Sherriff, Stevie Smith, Muriel Spark, Dylan Thomas, Edward Thomas, RS Thomas, William Trevor, Evelyn Waugh, Arnold Wesker, John Wyndham and WB Yeats.* • texts that enable students to make connections between experiences across times and literary traditions • texts that enable students to analyse the values and assumptions of writing from different cultures and traditions, relating and connecting them to their own experience, with the following examples*: Chinua Achebe, John Agard, Monica Ali, Moniza Alvi, Maya Angelou, Isaac Bashevis Singer, James Berry, Edward Braithwaite, Anita Desai, Emily Dickinson, F Scott Fitzgerald, Athol Fugard, Jamila Gavin, Nadine Gordimer, Doris Lessing, Arthur Miller, Les Murray, Beverly Naidoo, RK Narayan, Grace Nichols, Ruth Prawer Jhabvala, Bali Rai, Wole Soyinka, John Steinbeck, Meera Syal, Mildred D Taylor, Mark Twain, Derek Walcott, Walt Whitman, Tennessee Williams, Adeline Yen Mah and Benjamin Zephaniah. The study of texts by these authors should be based on whole texts and presented in ways that will engage students* • at least one play by Shakespeare. **Non fiction and non-literary texts** • forms such as journalism, travel writing, essays, reportage, literary non-fiction, print media and multimodal texts including film and television • purposes such as to instruct, inform, explain, describe, analyse, review, discuss and persuade.

Massachusetts (2001)

Massachusetts' specification covers both primary and secondary, setting out its list in blocks of years from Reception to Year 13. There are two lists: the first specifies authors, illustrators, and works which reflect common American literary and cultural heritage; the second lists authors of literature from around the world. Both are split further into more specific genres for each block of years[68]. Some specific examples are included in Table 3.7 for Years 6 to 9.

[68] Massachusetts Department for Education (2001) *Massachusetts English Language Arts Curriculum Framework.* http://www.doe.mass.edu/frameworks/ela/0601.pdf

Table 3.7: Example of reading list in Massachusetts (2001)

	Suggested authors, illustrators and works reflecting our common literary and cultural heritage	Suggested authors and illustrators of contemporary American literature and world literature
Reception –Year 3	**For reading, listening, and viewing** **The Bible as literature** **Picture book authors and illustrators** **Poets**	**Contemporary literature of the United States**
Years 4–5	**Traditional literature** **The Bible as literature** **American authors and illustrators** **British authors** **Poets**	
Years 6–9	**Traditional literature** • Grimm's fairy tales, French fairy tales, Tales by Hans Christian Andersen and Rudyard Kipling, Aesop's fables *[list continues]* **The Bible as literature** • Old Testament, Genesis, Ten Commandments, Psalms and Proverbs • New Testament: Sermon on the Mount, Parables **American authors or illustrators** • Louisa May Alcott, Lloyd Alexander, Natalie Babbitt, L. Frank Baum, Nathaniel Benchley, Carol Ryrie Brink, Elizabeth Coatsworth *[list continues]* **British and European authors or illustrators** • James Barrie, Lucy Boston, Frances Burnett, Lewis Carroll, Carlo Collodi, Daniel Defoe, Charles Dickens, Arthur Conan Doyle *[list continues]* **Poets** • Stephen Vincent and Rosemarie Carr Benet, Lewis Carroll, John Ciardi, Rachel Field *[list continues]*	
Years 10–13	**Traditional and Classical literature** **The Bible as literature** **American Literature** • Historical documents of literary and philosophical significance • Important writers of the 18th and 19th centuries • Important writers of the first half of the 20th century • Playwrights • Poets • Immigration experience **British and European Literature** • Poetry, Drama, Essays and Fiction	**Contemporary American Literature** • Fiction • Poetry • Essay/ non-fiction (contemporary and historical) • Drama **Historical and Contemporary World Literature** • Fiction • Poetry • Essay/ non-fiction • Drama • Religious Literature

Alberta (2005)[69]

The Alberta curriculum includes supplementary guidance that sets out novels and non-fiction titles year by year for Years 5 to 11. The list is annotated, providing a short quotation from the text, along with suggested themes and literary features for study. Canadian texts are identified with a '(C)' throughout the document (see Table 3.8). The titles have been selected for their suitability for pupils' ages, abilities and social maturity, and other criteria as appropriate for their year group. Table 3.8 sets out an extract from the reading list for Year 9 pupils, along with an annotation for one of the texts, 'Holes'[70].

Table 3.8: Example of reading list in Alberta (2005)

English Language Arts Novels and Nonfiction—Grade 8

- Artemis Fowl
- The Dark Is Rising
- Dragonwings
- Freak the Mighty
- The Giver
- **Holes**
- Invitation to the Game (C)
- Journey to the River Sea
- Kensuke's Kingdom
- Looking Back: A Book of Memories
- The Master Puppeteer
- Redwork (C)
- The Seeing Stone
- Shadow in Hawthorn Bay (C)
- Shane
- Shipwrecked! The True Adventures of a Japanese Boy
- A Single Shard
- The True Confessions of Charlotte Doyle
- The Tuesday Café (C)
- Under the Blood-Red Sun
- Walk Two Moons
- What They Don't Know (C)
- Winners (C)

Example: HOLES, Louis Sachar

In **Holes**, Stanley Yelnats finds himself plunked down in Camp Green Lake, a work-camp for juvenile delinquents, after being wrongfully accused of theft. Stanley discovers there is no lake, just a gigantic, dry wasteland where daytime temperatures hover around 95 degrees in the shade. All of the boys are sent out each day in the heat to dig holes. The warden, it seems, is convinced that there is buried treasure on the site. When Stanley digs up a tiny cartridge with the initials 'KB' on it, enclosed in the shape of a heart, he's sure he has found a clue.

Stanley learns that one hundred and ten years ago, Katherine Barlow, the schoolteacher, refused an offer of marriage from the son of the richest man in the country. Instead, she fell in love with Sam, a negro. There was a law in Texas forbidding their romance, so the gentle schoolmarm became the notorious outlaw Kissin' Kate Barlow.

Holes subtly addresses the themes of justice and friendship through a humorous, descriptive and accessible style that has wide appeal for students.

"*One thing was certain: They weren't just digging to build character. They were definitely looking for something. And whatever they were looking for, they were looking in the wrong place. Stanley gazed out across the lake, toward the spot where he had been digging yesterday when he found the gold tube. He dug the hole into his memory*." p. 71

This novel has support videos available through ACCESS: All About the Book: A Kid's Video Guide to "Holes," 2002 [21 min. BPN 2076103], Good Conversation: A Talk with Louis Sachar, 1999 [21 min. BPN 2075912] and Holes (feature film) [120 min. BPN 2079101].
Awards: ALA Best Books for Young Adults, 1978

[69] The reading list for Alberta was last updated in 2005.
[70] Alberta Education (2005) *English Language Arts: authorized novels and non-fiction annotated list.* *http://education.alberta.ca/teachers/program/english/resources/ela-list.aspx*

Denmark[71]

There are two distinct elements to Denmark's reading list: a list of suggested texts for primary and secondary phases, and a literary reading list which comprises texts from 15 Danish authors. It is expected that each of the texts from the reading list will be covered between Years 3 and 11 and is not age-specific, giving teachers the autonomy to use the texts as they feel appropriate, and to choose additional texts without restrictions.

Poland (2006)

In Poland, there is no compulsory reading list, although recommended authors or titles are listed as part of the core curriculum document. Where a title or author is not stipulated, there is often reference to genre, with the teacher required to select a suitable text to meet the criteria. Table 3.9 summarises the coverage of text titles as set out in the Polish core curriculum document for Years 9 to 11[72].

Table 3.9: Example of reading list in Poland (2006)

For the Polish language works include:

- The Bible
- A choice of myths
- Homer
- Sophocles
- Shakespeare
- Cervantes
- Song of Roland
- Dickens (two novels to choose from)
- De Saint-Exupéry
- Hemingway
- Chekhov

Polish literature includes:

- Miron Bialoszewski "A Diary of the Warsaw Uprising"
- Bogurodzica
- A choice of Renaissance and Baroque poetry
- Jan Kochanowski selected poems
- Krasicki selected poems
- Mickiewicz selected poems, "Dziady" part 2 and "Pan Tadeusz"
- Slowacki "Balladyna"
- Fredro "Zemsta"
- Prus and Zeromski ("Syzyfowe prace") (19th century writers)
- Modern Polish literature such as diaries, memoirs, correspondence, journalism, literature from the local area, texts from the daily press
- Popular literature (at least one text in each year).

Reading for research

Each curriculum varies in the degree to which it specifies *research activities*, as detailed in Table A2 (Appendix A). The majority of the jurisdictions cover the same ground, with pupils expected to select and read a range of reference

[71] Date publication unknown. (See Eurydice (2007). *National Literature Canon.* http://www.nfer.ac.uk/shadomx/apps/fms/fmsdownload.cfm?file_uuid=A981D4AF-C29E-AD4D-04C0-3715224EB1D0&siteName=nfer).

[72] Eurydice (2007). *National Literature Canon.* http://www.nfer.ac.uk/shadomx/apps/fms/fmsdownload.cfm?file_uuid=A981D4AF-C29E-AD4D-04C0-3715224EB1D0&siteName=nfer

or non-fiction texts to suit the purpose of the task.

At primary level, the focus is on pupils being able to organise the task of finding information (such as using reference materials and libraries), generating questions for research and summarising findings. At secondary, emphasis is given to search criteria for selecting texts, synthesising the information, and using and evaluating sources.

Alberta, Singapore and Massachusetts have the most detailed requirements for reading for research and information at both primary and secondary phases. In Alberta, detailed strategies are set out for learning to read for information as part of the *Managing ideas and information* General Outcome. Pupils are expected to plan and determine their information needs before selecting and processing a range of sources. Pupils are taught to interpret and analyse the text and then to evaluate the success of the strategies they used.

New South Wales and New Zealand have less detail in their curricula: New Zealand simply identifies the need to select and read a wide range of written informational texts, giving very little detail on strategies for selecting or reading these. New South Wales focuses on the use of technology, both for written and visual language texts.

England's 1999 and 2007 secondary curriculum documents make only minor reference to the process of reading for information in Years 7–11, and this is mostly in connection with electronic texts and other media sources. In comparison, the Alberta curriculum[73] is far more detailed, setting out requirements for reading as part of the research process. Table 3.10 shows the difference between the England (1999) and Alberta curricula.

Table 3.10: Example of reading for research in England (1999) and Alberta (2000)

England 1999 – Years 7-11	Alberta 2000 – Year 8
Printed and ICT-based information texts To develop their reading of print and ICT-based information texts, pupils should be taught to: • select, compare and synthesise information from different texts • evaluate how information is presented • sift the relevant from the irrelevant, and distinguish between fact and opinion, bias and objectivity • identify the characteristic features, at word, sentence and text level, of different types of texts. **Media and moving image texts** Pupils should be taught: • how meaning is conveyed in texts that include print, images and sometimes sounds • how choice of form, layout and presentation contribute to effect (for example, font,	**Focus attention** **Determine information needs** **Plan to gather information** **Use a variety of sources** • obtain information from a variety of sources, such as adults, peers, advertisements, magazines, lyrics, formal interviews, almanacs, broadcasts and videos, to explore research questions **Access information** • use a variety of tools and text features, such as headings, subheadings, topic sentences, summaries, staging and pacing, and highlighting, to access information • distinguish between fact and opinion, and follow the development of argument and opinion • scan to locate specific information quickly; summarize and record information useful for

[73] Alberta combines reading, writing, speaking and listening across the English curricula, so these statements relate to the research process as a whole (both reading and writing) rather than being specific to reading.

caption, illustration in printed text, sequencing, framing, soundtrack in moving image text) • how the nature and purpose of media products influence content and meaning [for example, selection of stories for a front page or news broadcast] • how audiences and readers choose and respond to media.	research purposes **Evaluate sources** • use pre-established criteria to evaluate the usefulness of a variety of information sources in terms of their structure and purpose **Organize information** • organize ideas and information by selecting or developing categories appropriate to a particular topic and purpose **Record information** **Evaluate information**

Writing

Our analysis found that *writing* can be broadly split into five sub-domains across the curricula which cover:

- ***Planning***: considering the content, audience and purpose of a piece of writing through planning and preparation;

- ***Composition***: putting thoughts and information into writing; bringing together technical, presentational and creative aspects of writing;

- ***Evaluating, editing and proof-reading***: reviewing and evaluating one's own and others' writing, identifying and making improvements to the content and structure of the text, and correcting any errors;

- ***Grammar, spelling and punctuation***: using grammatical conventions in writing at word, sentence and text level. *Grammar* predominantly covers writing sentences and speaking correctly through the knowledge of a range of grammatical conventions. *Punctuation* features largely within *grammar* (e.g. sentence construction, dialogue) and *spelling* (e.g. contractions);

- ***Handwriting***: developing the fine motor skills and techniques for correct formation of letters and digits and developing a fluent, cursive and individual style.

Table A3 (Appendix A) sets out the characteristics of *planning, composition and editing* in each jurisdiction. There was a notable variation in the breadth and specificity amongst jurisdictions for these domains, more so for writing than for reading.

Planning
New Zealand, Singapore and England (1999) and (2007) all give very little detail on *planning writing* at primary or secondary level.

The New South Wales primary curriculum has detailed content on specific organisational techniques for writing, such as using *"a framework to make notes, e.g. matrix, flowchart, semantic map*" in Years 2–3. The secondary curriculum is much less detailed, setting out different purposes for which pupils should use planning.

Massachusetts is also quite detailed in its requirements for planning a piece of writing, for example, one of the planning requirements for Year 6-7 is:

> *"Decide on the placement of descriptive details about setting, characters, and events in stories. For example, when writing their own mystery stories, students plan in advance where clues will be located*"

In addition, the primary curriculum gives significant weight to undertaking research in preparation for writing, with some specific research skills covered. The secondary curriculum is less prescriptive, requiring pupils to:

> *"Organize ideas for a critical essay about literature or a research report with an original thesis statement in the introduction, well constructed paragraphs that build an effective argument, transition sentences to link paragraphs into a coherent whole, and a conclusion'*[74].

Composition

The curricula analysed have similar levels of specificity for *composition* (see Appendix A -Table A3), with the exception of Alberta and New South Wales, which both have greater specificity. England 1999, New Zealand, Singapore and Massachusetts all describe the required outcomes at a general level. Singapore and Alberta both combine many of the writing outcomes with those of speech.

At lower primary, *composition* centres on constructing meaningful sentences and converting these into longer texts (both stories and expository texts) with a basic structure. During the remainder of the primary phase, curricula commonly focus on pupils writing at increasing length, for a specific purpose; using more complex sentence and organisational structures; using language for effect; and developing a 'personal voice'. Genres of writing to be covered are set out in different ways, with New Zealand being unique in categorising writing into *expressive, poetic* and *transactional* sub-domains, while the 1999 England curriculum sets out the different forms for writing separately at each key stage. For example, at Key Stage 2, composition should include narratives, poems, playscripts, reports, explanations, opinions, instructions, reviews and commentaries.

The difference in approach between England and Alberta is exemplified by the extracts from these curricula in Table 3.11. While England's National Curriculum sets out in very general terms what pupils should be taught, Alberta gives detailed suggestions of how better composition could be achieved, covering both the structure of the text (*e.g.* "*beginnings, middles and ends*") and its possible purpose (*e.g.* "*demonstrate clear relationships between character and plot*").

Table 3.11: Example of composition in England (1999) and Alberta (2000)

[74] Massachusetts Department for Education (2001). *Massachusetts English Language Arts Curriculum Framework.*(p.66) http://www.doe.mass.edu/frameworks/ela/0601.pdf

England 1999, Years 3–6	Alberta 2000, Year 6
Composition Pupils should be taught to: • choose form and content to suit a particular purpose (for example, notes to read or organise thinking, plans for action, poetry for pleasure) • broaden their vocabulary and use it in inventive ways • use language and style that are appropriate to the reader • use and adapt the features of a form of writing, drawing on their reading • use features of layout, presentation and organisation effectively.	**Create original text** *[building on requirements set out in earlier years]* **Year 6** • use texts from listening, reading and viewing experiences as models for producing own oral, print and other media texts • experiment with modelled forms of oral, print and other media texts to suit particular audiences and purposes • use structures encountered in texts to organize and present ideas in own oral, print and other media texts • use own experience as a starting point and source of information for fictional oral, print and other media texts

At secondary level, the emphasis in all curricula moves to more sophisticated writing for more complex purposes. Pupils are expected to use and apply their skills and knowledge to adapt standard text types to suit the audience and purpose, developing a more fluent, personal style. Each jurisdiction focuses on developing coherent, well-structured whole texts to which pupils can apply their knowledge of writing conventions and techniques. The Singapore curriculum gives significantly less detail for composing texts at the secondary phase. Massachusetts has more content relating to the different forms of writing than other curricula, whilst New Zealand emphasises the importance of pupils having the appropriate terminology to describe their writing.

Evaluating, editing and proof-reading

There is significant variation in the specification of *evaluating, editing and proof-reading*. Alberta has the highest level of specificity, for example requiring Year 5 pupils to "*identify and reduce fragments and run-on sentences*" and "*edit for subject-verb agreement*." Once again, in the secondary phase curricula become much more general; in Alberta, for example, pupils in Year 10 should "*revise to combine narration, description and exposition effectively"*.

New Zealand and Singapore have very little content in relation to *evaluating, editing and proof reading*. In the case of Singapore, this is a notable omission in that it is at odds with the level of detail in the rest of the curriculum.

Massachusetts contrasts with England by specifying a list of sophisticated language features to be checked and revised. England does not do this at either primary or secondary, and furthermore does not mention checking for grammatical errors at all. Table 3.12 exemplifies Massachusetts' greater specificity and higher level of challenge (even after taking into account the one-year age difference).

Table 3.12: Example of planning, drafting and evaluating in England (1999) and Massachusetts (2001)

England 1999, Years 3–6	Massachusetts 2001, Years 6–7
Planning and drafting To develop their writing on paper and on screen, pupils should be taught to: […] • revise, change and improve the draft • proof-read and check the draft for spelling and punctuation errors, omissions and repetitions […] • discuss and evaluate their own and others' writing	**Revising** • Revise writing to improve level of detail and precision of language after determining where to add images, sensory detail, combine sentences, vary sentences and rearrange text. **Standard English Conventions** • Use additional knowledge of correct mechanics (apostrophes, quotation marks, comma use in compound sentences, paragraph indentations), correct sentence structure (elimination of fragments and run-ons), and correct standard English spelling (commonly used homophones) when writing, revising, and editing. **Evaluating Writing and Presentations** Year 4–5 • Form and explain personal standards or judgments of quality, display them in the classroom, and present them to family members. Year 6–7 • Use prescribed criteria from a scoring rubric to evaluate compositions, recitations, or performances before presenting them to an audience.

Grammar, spelling and punctuation

The extent of *grammar* and *punctuation* coverage varies considerably (see Appendix A - Table A3). New Zealand is notable for the absence of specific requirements for *grammar* and *punctuation* throughout its curriculum. England and New South Wales integrate *grammar* into other sections, while Massachusetts, Singapore and Alberta present *grammar* as a separate section of the curriculum.

The Singapore curriculum has a discrete and very detailed *grammar* strand which has a greater level of specificity and challenge than any of the other curricula analysed. For example, *connectors to do with time and sequence* and *modal auxiliaries* are introduced as learning outcomes for the end of Year 3 and are listed in relation to spoken and written texts.

The Massachusetts curriculum also sets out expectations of grammatical knowledge in some detail, and is more challenging than the England 1999 and 2007 secondary curricula. Table 3.13 illustrates how - at Years 10 and 11 - pupils in Massachusetts are expected to be able to use their knowledge of grammar to analyse sentence structure, including undertaking basic formal analysis using the transformational model.

Table 3.13: Example of grammar in England (1999) and Massachusetts (2001)

England 1999, Years 7–11	Massachusetts 2001, Years 10–11
Pupils should be taught the principles of sentence grammar and whole-text cohesion and use this knowledge in their writing. They should be taught: • word classes or parts of speech and their grammatical functions • the structure of phrases and clauses and how they can be combined to make complex sentences (for example, coordination and subordination) • paragraph structure and how to form different types of paragraph • the structure of whole texts, including cohesion, openings and conclusions in different types of writing (for example, through the use of verb tenses, reference chains) • - the use of appropriate grammatical terminology to reflect on the meaning and clarity of individual sentences (for example, nouns, verbs, adjectives, prepositions, conjunctions, articles).	• Identify simple, compound, complex, and compound-complex sentences. • Identify nominalized, adjectival, and adverbial clauses. • Recognize the functions of verbs: participles, gerunds, and infinitives. • Analyze the structure of a sentence *(traditional diagram, transformational model).* *For example, students analyze the clauses and phrases in the first two lines of Robert Louis Stevenson's poem, "My Shadow":* *"I have a little shadow that goes in and out with me,* *And what can be the use of him is more than I can see."* • Identify rhetorically functional sentence structure *(parallelism, properly placed modifiers).* • Identify correct mechanics *(semicolons, colons, hyphens),* correct usage *(tense consistency),* and correct sentence structure *(parallel structure).* • Describe the origins and meanings of common words and foreign words or phrases used frequently in written English, and show their relationship to historical events or developments *(glasnost, coup d'état).*

Alberta also has a separate section on *grammar*, although it is not particularly detailed on the specific grammar to be learnt. Most statements are fairly general, for example "*use a variety of strategies to make effective transitions between sentences and paragraphs in own writing"* (Year 6), or "*edit for subject-verb agreement*" (Year 5).

The picture for *spelling* is somewhat different from that of *grammar* (see Appendix A - Table A3), with Alberta being the most prescriptive, and Singapore and New Zealand giving very little detail. Alberta has greater coverage of *spelling* at secondary level than the other curricula, for example requiring pupils to "*identify and use variant spelling for particular effects, depending on audience, purpose, content and context*."

New South Wales (2007) and England's 1999 National Curriculum set out quite general spelling strategies for primary pupils and require pupils to broaden their knowledge and become more confident in spelling more complex and unfamiliar words. New Zealand makes little mention of spelling, specifying that it is one of the conventions pupils should use.

Speaking and listening

Speaking and *listening* are represented differently in each jurisdiction, either as separate domains (England, New Zealand, New South Wales primary) or integrated within other domains (Massachusetts, Alberta, Singapore and New

South Wales secondary). Table 3.14 shows the organisation of *speaking* and *listening* in each jurisdiction. Table A5 (Appendix A) has more detail on each of the curriculum documents.

Table 3.14: Speaking and listening in comparator jurisdictions

New South Wales 2007 (Years 1 to 7)	**England 1999 (Years 1 to 11)**
Learning to talk and listen **Talking and Listening** • Purpose • Audience, Subject Matter **Skills and Strategies** • Listening Skills • Interaction Skills • Oral Presentation Skills Learning about talking and listening **Context and Text** • Audience • Channel of Communication • Language Varieties **Language Structures and Features** • Text Structures and Features • Grammar • Expression	• Speaking • Listening • Group discussion and interaction • Drama • Standard English (also in reading and writing domains) • Language Variation (also in reading and writing domains)
New South Wales 2003 (Years 8 to11)	**England 2007 (Years 7 to 11)**
Through responding to and composing a wide range of texts in context and through close study of texts, students will develop skills, knowledge and understanding in order to: • speak, listen, read, write, view and represent • use language and communicate appropriately and effectively • think in ways that are imaginative, interpretive and critical • express themselves and their relationships with others and the world • learn and reflect on their learning through their study of English.	Speaking and Listening
Massachusetts 2001	**Alberta 2000**
Language: • Discussion • Questioning, Listening and Contributing • Oral Presentation • Vocabulary and concept development • Structures and Origins of Modern English (integrated with reading and writing) • Formal and Informal English (integrated with reading and writing)	*(Features in all 5 General Outcomes)* Students will listen, speak, read, write, view and represent to: • explore thoughts, ideas, feelings and experiences • comprehend and respond critically to oral, print and other media texts • manage ideas and information • enhance the clarity and artistry of communication • respect, support and collaborate with others
	New Zealand 1994
	Listening Functions • Interpersonal listening • Listening to Texts **Speaking Functions** • Interpersonal Speaking • Using Texts **Listening and Speaking Processes** • Exploring Language • Thinking Critically • Processing Information
	Singapore 2001
	• Language for Information • Language for Literary Response And Expression • Language for Social Interaction

The jurisdictions have a similar approach to *speaking* and *listening* at the primary and secondary phases. At primary level, the focus is generally on developing vocabulary, clear articulation, effective participation in discussion, oral presentations, and asking and answering questions. Developing comprehension through hearing and responding to texts read aloud is a significant part of all the curricula studied before word-reading is secure. Other than for Singapore, at secondary level the focus moves to presenting more complex information to a range of audiences, debating, adapting presentations for different audiences and processing complex information.

The approach taken by Alberta and, to a lesser extent, Singapore is distinctive, with the majority of outcomes and indicators in the Alberta curriculum applied to both *speaking* and *writing*. This gives *speaking* and *listening* almost equal prominence to *reading* and *writing*. For example, Table 3.15 shows how, in contrast to England, pupils in Alberta are expected to use dictionaries to support spoken as well as written language.

Table 3.15: Example of use of dictionaries and reference aids in England (1999) and Alberta (2000)

England 1999, Years 7–11	**Alberta 2000, Year 7**
Spelling Pupils should be taught to: […] • check their spelling for errors and use a dictionary when necessary • use different kinds of dictionary, thesaurus and spellchecker.	**Use references** • choose the most appropriate reference to confirm the spellings or locate the meanings of unfamiliar words in oral, print and other media texts

New South Wales sets out detailed primary learning outcomes for speaking and listening; for example, "*detects strategies that speakers use to influence an audience, e.g. emotive language, one-sided presentation of information, exaggerated claims*".

The curricula of England, Massachusetts and Singapore are broadly similar in their level of detail, with New Zealand again the least specific. The level of challenge and progression in the Singapore curriculum for speaking and listening is below that of the other curricula, particularly at secondary, with little progression from primary to secondary and with outcomes for speaking for Year 11 almost the same as those for Year 7.

Section 4 – Curriculum comparisons for mathematics

4.1 Introduction

This section first sets out the selection of five comparator jurisdictions based on the findings of the international comparison studies, followed by the initial findings from the content analysis of the mathematics curricula in five high-performing jurisdictions and the mathematics National Curriculum in England. The jurisdictions are: Finland; Flemish Belgium; Massachusetts, USA; Hong Kong; and Singapore.

The purpose of comparing the curricula has been to identify whether there are any similarities and differences between the curricula which could be used to inform the development of the National Curriculum in England. The content analysis focuses on the level of expectation of the statutory curricula for mathematics in high-performing jurisdictions compared to the 1999 and 2007 National Curricula for England. As stated in Section 1.3, the analysis does not include wider non-statutory guidance and other related resources. For this reason, the National Strategies' *Frameworks for teaching* - non-statutory guidance for the teaching of numeracy and mathematics, introduced by the previous Government - are not within the scope of this analysis.

The focus has been on the organisation, breadth, specificity and, where possible, the level of challenge and sequencing of content within comparable age-phases (see Appendix B for more detail). The analysis examines the aims and domains common to the mathematics curricula in the different jurisdictions.

A number of examples are provided showing key differences between the National Curriculum and the statutory curricula of high-performing jurisdictions, focusing in particular on where the content in high-performing jurisdictions appears more challenging than in England. These are intended to illustrate where the new National Curriculum for mathematics could be strengthened so that the content, standards and expectations are on a par with the highest-performing jurisdictions.

4.2 Key findings

- ***Whole number***: in comparison to England, Singapore and Hong Kong are more explicit about the need to secure conceptual understanding and the recall of multiplication facts before written methods are taught. Confidence, fluency and attainment in number are important for future performance in *algebra*.

- ***Fractions***: Singapore, Hong Kong, Massachusetts and Finland sequence more demanding content earlier in the domains of *fractions* and *decimals*, covering the majority of this sub-domain by the end of primary. Notably, Singapore and Hong Kong cover all four operations with *fractions* and *decimals* by the end of primary.

- ***Shape, space and measure***: of all the content domains the highest degree of variation in the way content is specified can be found in *shape, space and measure*. In the context of area and volume, Hong Kong, Singapore and Massachusetts appear to have higher expectations in the primary phase compared to England, Finland and Flemish Belgium.

- ***Algebra***: the majority of high-performing nations studied broadly cover the same algebraic curriculum content at the same time, with the exception of Hong Kong and Singapore. For example, Hong Kong appears the most challenging at the end of the primary stage, while Singapore is by far the most challenging in secondary by covering significantly more demanding content at an earlier stage, including introducing quadratic equations by the equivalent to Year 9 in England.

- ***Data, statistics and probability***: the majority of the high-performing systems, including Hong Kong, Singapore and Flemish Belgium, do not include *probability* until upper secondary. In contrast, England introduces *probability* significantly earlier, in upper primary and early secondary, but does not score significantly higher in related domains in TIMSS (2007).

4.3 Selecting comparator jurisdictions

The curriculum analysis first involved the selection of a small number of high-performing jurisdictions in mathematics to benchmark against England. Identifying comparator jurisdictions was in part based on a synthesis of the results from these international comparisons and also on whether an education system for the given jurisdiction is organised at a national or sub-national (state, province, region) level. The education system, including the setting of the statutory curriculum, is therefore at the level of the province. Given this, it was sometimes necessary to draw on other studies to identify regions with the highest performing pupils within a particular nation. The jurisdictions covered in each survey are set out in Table 4.1[75].

Table 4.1: Jurisdictions covered in recent waves of PISA and TIMSS

		Australia	Alberta	Flemish Belgium	Finland	Hong Kong	Massachusetts	New Zealand	Singapore
Maths	TIMSS 2007 *age 10*	☑	☑			☑	☑	☑	☑
	TIMSS 2007 *age 14*	☑				☑	☑		☑
	PISA 2009 *age 15*	☑	☑ (Can.)	☑ (Bel.)	☑	☑	☑ (US)	☑	☑

[75] PISA 2003 covered mathematics at age 15 but the OECD excluded the data for the UK from its international report because the UK fell short of the minimum school and pupil participation rates required by PISA.

The 2007 wave of TIMSS involved more than 60 participating education systems[76]. The minimum age of pupils tested at the fourth grade was 9.5, and the sample size was approximately 161,000 pupils in participating education systems, plus 22,000 pupils in benchmarking participant education systems. Hong Kong and Singapore were the highest scoring education systems for fourth grade mathematics, with average scale[77] scores of 607 and 599 respectively. The third highest performing education system was Chinese Taipei (576). England achieved an average scale score of 541, which was significantly higher than the scale average of 500.

The minimum age of pupils tested at the eighth grade was 13.5, and the sample size was approximately 222,000 pupils in participating education systems and 21,000 pupils in benchmarking participants[78]. The highest performing education system was Chinese Taipei, with an average scale score of 598. The second and third highest performing education systems for eighth grade mathematics were the Republic of Korea (597) and Singapore (593). England achieved an average score of 513, which was significantly higher than the scale average of 500[79].

The PISA 2009 tests were administered to around 470,000 15 year-old pupils from 65 participating education systems and economies. The highest scoring education systems for mathematics were Shanghai[80] (600), Singapore (562) and Hong Kong-China (555). England achieved a mean score of 493, which was not statistically significantly different from the OECD average of 496[81].

Although Finland and Flemish Belgium did not participate in the TIMSS 2007 study, they have been selected on the basis of other studies. Finland has performed consistently well in PISA mathematics tests since 2000; Finland also scored statistically significantly higher than England in the TIMSS 1999 mathematics tests, but has not participated in the more recent TIMSS studies. Flemish Belgium participated in TIMSS 2003 and scored statistically significantly higher than England in grade 4 mathematics[82].

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[76] Mullis, I.V.S. Martin, M.O. and Foy, P. (with Olson, J.F. Preuschoff, C. Erberber, E. Arora, A. and Galia, J.) (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[77] The metric for fourth and eights grade mathematics and science scores in TIMSS 2007 were set at 500 using country mean scores from TIMSS 1995. Both had a standard deviation of 100. Foy, P. Galia, J. and Li, I. (2008). *Scaling the Data from the TIMSS 2007 Mathematics and Science Assessments*. In Olson, J.F. Martin, M.O. and Mullis, I.V.S. (eds.) (2008). *TIMSS 2007 Technical Report*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[78] Joncas, M. (2008). *TIMSS 2007 Sampling Weights and Participation Weights.* In Olson, J.F. Martin, M.O. and Mullis, I.V.S. (eds.) (2008). *TIMSS 2007 Technical Report.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[79] Mullis, I.V.S. Martin, M.O. and Foy, P. (with Olson, J.F. Preuschoff, C. Erberber, E. Arora, A. and Galia, J.) (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[80] Shanghai achieved the highest score in the PISA 2009 mathematics tests, and the Shanghai curriculum is of interest to the National Curriculum review. Research into the Shanghai mathematics curriculum is ongoing, but is not sufficiently developed to include in this report.
[81] Bradshaw, J. Ager, R. Burge, B. and Wheater, R. (2010). *PISA 2009: Achievement of 15-Year-Olds in England*. Slough: NFER.
[82] Mullis, I.V.S. Martin, M.O. Gonzalez, E.J. and Chrostowski, S.J. (2004). *TIMSS 2003 International Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and*

Among all the jurisdictions taking part in the above studies, it is possible to identify five jurisdictions with the highest achieving pupils in mathematics. The selected jurisdictions are:

- Finland;
- Flemish Belgium;
- Hong Kong;
- Massachusetts, USA; and
- Singapore.

4.4 Curriculum analysis for mathematics – an overview

The purpose of the content analysis is to draw out key similarities and differences in the breadth, the level of specificity and – where possible – the level of challenge and sequencing (see Appendix B). Although not every domain or sub-domain of school mathematics is examined, the analysis is intended to give a clear indication of how the curricula vary and what can be learned from high-performing jurisdictions.

Breadth

The content analysis showed significant commonality in how jurisdictions organise their mathematics curriculum. The curricula analysed were found to be principally content-oriented by being focused on a number of traditional mathematical domains, specifically:

- *Whole number and the four operations*;
- *Fractions, decimals and the four operat*ions;
- *Shape, space and measure*;
- *Algebra*;
- *Data, statistics and probability*.

Curriculum aims and mathematical processes were also a common feature of all the curricula analysed, though the approach varied across the different jurisdictions.

Specificity

The curricula set out on a year-on-year basis generally give a clearer indication of the level of expectation and progression compared to longer age phases. Those that organise a large proportion of their curriculum by year are Hong Kong, Singapore and Massachusetts. For primary, Hong Kong organises its curriculum on both an age phase and year-on-year basis but only uses longer age phases at secondary level. The majority of Singapore and Massachusetts are organised year-on-year. In contrast, curricula in England, Flemish Belgium and Finland are organised into longer age phases (see Table 1.2 for a detailed comparison of ages and phases across

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Eighth Grades. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Boston College.

jurisdictions). However, it is worth noting that in the case of the National Curriculum in England, Attainment Targets with the 8 level structure sit alongside the Programmes of Study. This enables a clearer assessment of progression and challenge than curricula with similar age phase structures such as Finland and Flemish Belgium.

In general, the analysis found that England (1999), Singapore, Hong Kong and Massachusetts are the most prescriptive and detailed curricula. This finding is true in terms of their content structure (e.g. year-on-year and Attainment Targets) but also in the way in which the domains and sub-domains are broken down into further detail. For example, they specify domains into a greater number of steps and provide exemplification to support interpretation of challenge and approach. The 2007 England National Curriculum for secondary is far less specific compared to the 1999 version as the Programme of Study only contains very broad statements for domains. Therefore, the 2007 Attainment Targets statements provide the only clear indication of the level of challenge and progression. Similarly, Flemish Belgium and Finland lack this detail.

More specifically, the domain of *number* in primary is specified more precisely in Hong Kong and Singapore compared to England (1999). There is a greater specification of *algebra* and *geometry* in the secondary phase in Hong Kong and Singapore compared to other jurisdictions, including England (2007). The domain of *data, statistics and probability* is the least specified overall across all jurisdictions, with the exception of England (1999).

It is also notable that the Singapore curriculum is more highly specified in primary than in secondary. The primary curriculum has a strong emphasis on pupils mastering the particular content of each year and excluding more challenging content from being introduced until later. There is also an explicit emphasis of factual, procedural and conceptual knowledge throughout.

Challenge

Although there is high commonality of content across the curricula analysed, there are some differences in the sequencing of content and age-related expectations. In some cases this is difficult to determine given the differences in the age-phase structure of curricula. However, the analysis indicates that the curricula in Hong Kong, Singapore and Massachusetts generally appear to be more demanding than in other jurisdictions, particularly for *number* and *algebra*. More specifically, this is most apparent in the domains of *number (whole numbers and fractions/decimals),* in which pupils are expected to understand and use whole numbers, fractions and decimals with increasing sophistication – including operations with numbers (add, subtract, multiply and divide). In addition, in the domain of *algebra*, Hong Kong demands most in primary compared to other jurisdictions, while the Singapore curriculum is significantly more challenging in secondary, particularly apparent in the earlier introduction of *quadratic equations*.

In contrast, compared with the other jurisdictions, the National Curriculum for

England appears more demanding for *data, statistics and probability*. This difference in challenge is most notable in primary. However, towards the end of secondary, the differences in challenge and breadth between England, Hong Kong and Singapore and other jurisdictions begin to level out.

4.5 Curriculum aims

Curriculum aims for mathematics were clearly specified in all the curricula analysed, although the amount of detail across jurisdictions differed. The purpose is mainly to frame the curriculum within a coherent conceptual framework for teachers, as well as to define the subject itself as a coherent and inter-connected discipline. The importance of mathematics to all aspects of life and its centrality to all major scientific technological advances is covered by all curricula, to varying degrees. In summary, curriculum content on the aims of a mathematics curriculum can be grouped into four overarching aims:

- *developing fluency in acquiring and applying mental and written procedures underpinned by mathematical concepts*

The notion of conceptual understanding and application of these mathematical concepts is articulated in most detail in Hong Kong and Singapore e.g. in relation to number, measure, algebra, appreciating and formalising structures and patterns. As part of this notion, all curricula emphasise the importance of pupils becoming fluent in recalling facts and using mental and written methods accurately.

- *solving problems in unfamiliar contexts, including real life, scientific and more formal mathematical problems*

This notion includes breaking down problems into a series of simpler problems or steps; making decisions about gathering, processing and calculating to acquire new information; and showing perseverance in finding solutions. This is most specific in Finland, Hong Kong and Singapore.

- *reasoning mathematically by following a line of enquiry to deduce and present a justification or argument using mathematical language*

This notion includes analysing information presented in different forms, recognising what additional information may be needed; identifying relationships, applying logical reasoning, making generalisations and communicating thinking with mathematical language. Among all the curricula, Singapore is most specific in the use of mathematical language to communicate ideas and arguments.

- *developing positive attitudes towards mathematics*

Whilst promoting a positive attitude towards mathematics is implicit in all curricula, Hong Kong and Singapore provide more detail on attitudes in their aims, including defining this as a separate domain about the fostering of appreciation, interest, confidence and perseverance in mathematics.

4.6 Mathematical processes

Curriculum aims for mathematics within each jurisdiction are invariably translated into a more detailed specification of particular kinds of mathematical processes. These processes are commonly specified separately to the domains of, for example, *number* and *geometry*, and are intended to work across these domains. The intention is primarily to ensure that teachers focus on all aspects of mathematics education, including the: factual (e.g. number bonds, multiplication tables); procedural (e.g. performing accurately particular written or mental calculations); and conceptual (e.g. understanding the multiplicative relationship between length, width and area of a rectangle). The development of quick recall, accuracy and fluency in parallel with the development of understanding and reasoning are all required to promote sound mathematical development.

There is a growing body of research[83] [84] that explores different aspects of mathematics teaching and learning, including the relationship between factual, procedural and conceptual knowledge. While individual studies[85] [86] [87] explore specific aspects of this knowledge, the wider debate is starting to move away from the opposition of conceptual understanding from factual and procedural knowledge. For example, the recent Ofsted survey of good practice in primary mathematics shows that many successful schools teach both fluency in mental and written methods of calculation, and understanding of the underlying mathematical concepts[88].

Indeed, there is a wider consensus amongst mathematics educators that conceptual understanding, procedural and factual fluency and the ability to apply knowledge to solve problems are all important and mutually reinforce each other. While a different emphasis on individual processes may occur during primary and secondary, a combination of all these processes is required for pupils to become adaptable mathematical problem-solvers. Within this there is also broad consensus that automatic retrieval of basic facts facilitates the solving of more complex problems[89].

Solving problems is central to mathematical proficiency and is articulated to a

[83] Nunes,T.,Bryant,P., Barros, R. & Sylva, K.(2011). *Development of Maths Capabilities and Confidence in Primary School* DCSFF Research Report RR118.

[84] Heid, M.K. (undated) *Mathematical Knowledge for Secondary School Mathematics Teaching*. http://tsg.icme11.org/document/get/744

[85] Skwarchuk, S-L (2008). *Look who's counting! The 123s of Children's Mathematical Development During the Early School Years.* *http://literacyencyclopedia.ca/pdfs/Look_Who's_Counting!__The_123s_of_Children's_Mathematical_Development_During_the_Early_School_Years.pdf*

[86] Dowker, A. (2009). *What Works for Children with Mathematical Difficulties?* DfES Research Report RR554

[87] Geary, Liu, Chen, Saults & Hoard, 1999 cited in Campbell, J. (2005). *Handbook of Mathematic Cognition.* New York, NY: Psychology Press.

[88] Ofsted, (2011) Good practice in primary mathematics: evidence from 20 successful schools. http://www.ofsted.gov.uk/resources/110140

[89] Cowan, R., Donlan, C. Shepherd, D-L, Cole-Fletcher, R., Saxton, M. & Hurry, J. (2011). B*asic Calculation Proficiency and Mathematics Achievement in Elementary School Children.* Journal of Educational Psychology Vol.103 Issue 4 pp786-803

varying degree across the international curricula. Singapore applies the highest degree of specificity to it, placing it at the centre of all mathematical learning. Its curriculum clearly articulates the development of all mathematical concepts, skills, attitudes and processes through a problem-solving approach, both in number and through simple and complex word problems.

4.7 Domains

In the following analysis, the focus is on a selection of domains and sub-domains for illustrative purposes, rather than a comprehensive analysis of all the content. Exemplar domain content across jurisdictions is shown below in tables against the equivalent year content covered in the 1999 National Curriculum and 2007 National Curriculum for England where relevant (see Appendix B, Tables B1-B6).

The mapping suggests that despite some variation in structure and organisation, there is a commonality of content in mathematics disciplines that can be organised into domains and sub-domains.

These are:

- *Whole number and the four operations;*
- *Fractions, decimals and the four operations;*
- *Shape, space and measure;*
- *Algebra; and*
- *Data, statistics and probability*.

Mathematical processes, referred to above, are positioned within curricula to work across each of the mathematical domains of *number*, *geometry and measure* and *data, statistics and probability*. Factual recall and procedural accuracy are particularly important for *number*, *fractions* and *algebra*. However, these are put alongside content that emphasises conceptual understanding and solving problems using these techniques.

Whole number and the four operations

In this domain, the analysis concentrated on the introduction, sequencing and development of multiplication and division using whole numbers. *Number* at primary is of particular interest. Research in mathematics education[90] indicates that a good understanding of conceptual and procedural operations in number is important for subsequent mathematical fluency and understanding. The analysis below draws out some key points of interest in the years in which particular concepts and methods are introduced and developed.

For example, in focusing on how multiplication and division are introduced and developed in each of the jurisdictions, there is a common pattern in the way each curriculum focuses on: conceptual understanding underpinning

[90] Nunes,T., Bryant,P., Barros, R. & Sylva, K.(2011). *Development of Maths Capabilities and Confidence in Primary School* DCSF Research Report RR118

multiplication and division (e.g. multiplication as repeated addition; the relationship between multiplication and division; multiplication as area); mental methods through the recall of multiplication and division facts; written methods for more complex multiplication and division; and applying this knowledge to solve problems.

Generally these dimensions are made explicit in all of the curricula examined and all appear to cover them by the end of primary[91] (see Table 4.2 for development of multiplication and division across jurisdictions). However, it is more difficult to establish progression in the Flemish Belgium and Finland curricula as they are both generally specified at a very high level. This includes content being defined over a single 6-year age phase in the Flemish Belgium curriculum. Formal education commences two years later in Finland, meaning key stages are less comparable to England. Progression is clearer in England, Hong Kong and Singapore as they show comparable content between Years 1 to 6. See Table 4.3 for comparison of content between England. Hong Kong and Singapore (See also Appendix B, Tables B1-B3).

Table 4.2: Overview of the introduction of multiplication and division written methods across jurisdictions

	England (1999)	Singapore (2001)	Hong Kong (2000)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000; 2004)
Introduction of concept	Year 1 -2	Year 1-2	Year 3	Not explicit	Year 3-4	Year 3
Multiplication & division facts	Year 2	Year 3	Year 3	Year 2-7	Year 3-4	Year 4- 5
Written methods	Year 3-6	Year 4 (mult'n) Year 5 (division)	Year 4	Year 2-7	Year 5-6	Year 4 -5

[91] In Flemish Belgium conceptual understanding underpinning multiplication and division is not fully explicit in the document outlining their end of primary outcomes.

Table 4.3: Example of difference in demand in multiplication and division in England (1999), Hong Kong (2000) and Singapore (2001)

	England (1999)	Hong Kong (2000)	Singapore (2001)
Introduction of concept	**Year 1-2** Understand multiplication as repeated addition; understand that halving inverse of doubling.	**Year 3** Develop conceptual understanding of multiplication (repeated addition).	**Year 2** Understanding of multiplication as repeated addition; problem solving using pictorial representations Multiplication with products no greater than 40.
Multiplication and area	**Year 3-6** Find areas of *rectangles* using the formula, understanding the connection to counting squares and how it extends this approach *Attainment Targets:* Find areas by counting squares (Level 4 Attainment Target 2007 - national expectation at Year 6) Pupils understand and use the formula for the area of a rectangle (Level 5 Attainment Target 2007)	**Year 5** Develop the concept of area. Understand and apply the formulae for calculating the area of *squares and rectangles*	**Year 4** Compare the area of shapes in non-standard units Use formula to calculate the area of a square and a rectangle
Multiplication and division facts	**Year 1-2** x2 and x10 and related division facts **Year 3-6** Recall multiplication facts to 10 x 10 and use then to derive quickly the corresponding division facts *Attainment Targets:* Mental recall of the 2, 3, 4, 5 and 10 times tables and derive the associated division facts (Level 3 Attainment Target – national expectation) Mental recall of multiplication facts up to 10 x 10 and quick derivation of corresponding division factors (Level 4 Attainment Target - national expectation end of Year 6)	**Year 3** Construct multiplication tables to 10	**Year 3** Times tables and related division facts for 2,3,4,5 and 10 **Year 4** Memorise all tables to 10 x10 and related division facts

	England (1999)	Hong Kong (2000)	Singapore (2001)
Written methods	**Year 3-6** Use written methods for short multiplication and division by a single-digit integer of two-digit then three-digit then four-digit integers Use long multiplication, at first for two-digit by two-digit integer calculations, then for three-digit by two-digit calculations Extend division to informal methods of dividing by a two-digit divisor (for examples, 64 ÷ 16), use approximations and other strategies to check that their answers are reasonable *Attainment Targets:* Solve whole number problems involving multiplication and division including those that give rise to remainders (Level 3 Attainment Target) Use efficient written methods of short multiplication and division. (Level 4 Attainment Target – national expectation at end Year 6) Understand and use an appropriate non-calculator method for solving problems that involve multiplying and dividing any three-digit number by any two-digit number (Level 5 Attainment Target) – above national expectation at end of Year 6.	**Year 4** Multiplication and division of 2 or 3 digits by 1 digit **Year 5** Perform 2-digit by 3-digit multiplication Perform written division with 2 digit divisor and 3 digit dividend	**Year 4** Multiplication and division of up to 3 digits by 1 digit **Year 5** Division of numbers up to 4 digits by 1 digit whole number and by 10 Multiply numbers up to 3 digits by a 2 digit number and up to 4 digits by 1 digit. **Year 6** Division of numbers up to 4 digits by a 2 digit whole number

There are various sub-domains that support conceptual understanding of multiplication and division. Content that relates to conceptual understanding (e.g. halving and doubling; multiplication as repeated addition) is clearly introduced early – around Years 1-3 across all jurisdictions – either before or around the same time as the introduction of some multiplication and division facts in England, Hong Kong and Singapore. Singapore seems to go further in articulating a conceptual foundation by focusing on ‘products no greater than 40’ and ‘solving problems using pictorial representations’.

The concept of area – particularly areas of rectangles - also supports conceptual understanding of multiplication (see Table 4.3 and Table 4.7 in *Shape, space and measure*). In England, the national expectation at the end of Year 6 is to count squares to calculate an area (Level 4) while the relationship between length, width and area is limited to the use of a formula and then is only for pupils working above national expectation (Level 5). Hong Kong and Singapore appear to have higher expectations by the end of primary, introducing calculating area of rectangles, including with a formula, in Year 5 and 4 respectively. In addition, they expect understanding of the area of other shapes (see Table 4.7).

Content that relates to multiplication and division facts differs across the curricula. England introduces simple multiplication tables earlier at Year 2, with the expectation that all the 10 x 10 facts are secure by the end of Year 6. Hong Kong and Singapore, by contrast, introduce some 10 x 10 facts from Year 3, and in Singapore it is expected that all these facts are taught by the end of Year 4.

Written methods for multiplication and division also differ. All three jurisdictions expect multiplication and division of multi-digit numbers by single-digit numbers early on: from Year 3 for England and Year 4 for Hong Kong and Singapore. This is extended to long multiplication: 3-digit by 2-digit numbers for Year 5 in Hong Kong and Singapore and up to Year 6 in England. However, a written method for division with 2-digit divisors is only expected in Hong Kong and Singapore, in Year 5 and Year 6 respectively. The expectation in England for 2-digit divisors is limited to informal methods and an efficient written method is not the national expectation at the end of Year 6. Instead, it is only specified as a desirable outcome for those pupils working above national expectation at the end of Year 6.

Although the importance of an efficient written method with 2-digit divisors – sometimes called long division – is hotly debated, the more general observation is that the curricula in Singapore and Hong Kong make more explicit the need to secure some conceptual understanding and the recall of multiplication facts before written methods are taught. This is made explicit through the year-on-year curriculum, which allows for clearer articulation of this progression. In addition, expectations around developing multiplicative concepts – through for example repeated addition and area – are also expected earlier.

Fractions

As with whole number and the operations, fractions are of particular interest given the added complexity of number and the importance of both factual and procedural fluency and conceptual understanding. Commonly expressed as a numerator and denominator, fractions (e.g. ¾) can represent many different mathematical entities such as part-whole relations, decimals, ratios and probabilities.

Moreover, proficiency of fractions is considered essential for accessing the secondary mathematics curriculum, in particular in the domains of *measure*, *algebra*[92] and *geometry* as well as *probability*. For example, proportional reasoning and understanding intrinsic quantities such as density are part of the conceptual understanding that should underpin the use of fractions and associated mathematical terms such as ratios. However, pupils' development of both conceptual and procedural knowledge of these quantities has been identified as a key difficulty[93]. Research suggests that proficiency in relation to fractions, and mathematics more generally, is improved when there is an emphasis on quantitative relations and equivalencies[94] [95] [96] [97].

The curriculum analysis undertaken on *fractions* (see Appendix B, Table B4) is limited to the initial introduction of *fractions*, *decimals*, equivalence between fractions and decimals and calculations with the four operations. It was found that the curricula cover the same breadth of content and challenge in these dimensions. The differences between the curricula lie in the way the content is broken down, sequenced, and described. Tables 4.4 and 4.5 provide an overview of how conceptual and procedural sub-domains within *fractions* and *decimals* are introduced across jurisdictions.

All the curricula, including England, introduce the concept of *fractions* over the course of Years 3-7, including part-whole relationships, decimals, unit fractions, equivalent fractions, equivalence with decimal numbers, common factors and simplification of fractions. Where most high-performing jurisdictions bar Finland differ quite markedly from England is in the earlier introduction of equivalencies between fractions, decimals and percentages and calculations with fractions and decimals (see Table 4.5).

For example, Singapore, Flemish Belgium and Massachusetts include equivalencies with percentages around Years 6-7, while Finland and England do not set expectations until around Years 8-9. In addition, unlike England, all the other curricula include some expectation that pupils will be taught to develop addition, subtraction, multiplication and/or division of fractions in late primary. Singapore, Hong Kong, Massachusetts and Finland sequence more

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[92] The US National Mathematics Advisory Panel (2008) reviewed a significant body of research and identified the 'Critical Foundations of Algebra' which emphasises proficiency with fractions (including decimals) were an important pre-cursor to later achievement in algebra and should be mastered in elementary and middle school: addition and subtraction of fractions and decimals should be proficient by equivalent of end of Year 6; multiplication and division of decimals and fractions should be proficient by equivalent of end of Year 7.

[93] Howe, C., Nunes, T., Bryant, P., (2010). *Rational number and proportional reasoning: using intensive quantities to promote achievement in mathematics and science*. International Journal of Science and Mathematics Education Vol.9, No. 2 pp391-417

[94] Howe, C., Nunes, T., Bryant, P., D. Bell, D., Desli, D. (2010). *Intensive quantities: Towards their recognition at primary level; Understanding Number Development and Difficulties*. BJEP Monograph Series II, Number 7 Vol.28 Issue 2 pp307-329.

[95] Howe, C., Nunes, T., Bryant, P., (2010). *Intensive quantities: Why they matter to developmental research*; British Journal of Developmental Psychology, 28, 307-329.

[96] Nunes, T., Bryant, P., (2009). *Understanding rational numbers and intensive quantities; Key Understandings in mathematics learning*. London: Nuffield Foundation.

[97] Howe, C., Nunes, T., Bryant, P., (2010). *Rational number and proportional reasoning: using intensive quantities to promote achievement in mathematics and science*. International Journal of Science and Mathematics Education Vol.9, No. 2 pp391-417

demanding content earlier than England, covering the majority of this sub-domain by the end of primary[98]. England and Flemish Belgium do not include calculations with fractions until Year 7 and beyond (see Table 4.5).

Table 4.4: Overview of conceptual development of fractions and decimals and key equivalencies across jurisdictions

	England (1999; 2007)	Hong Kong (1999; 2000)	Singapore (2001)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000; 2004)
Introduction of fractions	Year 3-6	Year 4	Year 3	Year 2-7	Year 3-4	Year 4
Introduction of decimals	Year 3-6	Year 5	Year 5	Year 2-7	Year 3-4	Year 5
Introduction of equivalencies between fractions and decimals	Year 3-6	Year 5	Year 5	Year 2-7	Year 5-7	Year 5
Introduction of equivalencies between percentages and fractions/ decimals	Year 7-9 (Level 6 Attainment Target, 2007)	Year 7	Year 6	Year 2-7	Year 8-11	Year 6

Among the curricula analysed, Hong Kong and Singapore seem to be the most demanding in expecting all four operations to be introduced in some form by Year 6. For a detailed view of the level of challenge of calculations with fractions in primary in these jurisdictions in comparison to England, see Table 4.6. For example, in Year 6, Singapore expects pupils to be taught to multiply proper fractions with a proper or improper fraction and to divide proper fractions with whole numbers. Hong Kong is more challenging in primary in relation to division of fractions and expects pupils to be taught to divide fractions with fractions.

[98] End of primary key stage in Finland includes equivalent to England Year 7, so these findings need to be interpreted with caution.

Table 4.5: Overview of fractions and decimals across jurisdictions

	England (1999; 2007)	Hong Kong (1999; 2000)	Singapore (2001)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000; 2004)
Fractions: Addition and subtraction with like denominators	Year 7-9 (Level 6 Attainment Target, 2007)	Year 5	Year 3-5	Year 2-7; 8-9	Year 5-7	Year 5 & 6
Fractions: Addition and subtraction with unlike denominators	Year 7-9	Year 6	Year 5 & 6	Year 8-9	Year 5-7	Year 6
Fractions: Addition & subtraction with mixed numbers	Year 7-9	Year 6	Year 6	Year 8-9	Year 5-7	Year 6
Fractions: Multiplication by whole numbers	Year 7-9	No reference	Year 5	Year 2-7 (simple fractions only)	Year 5-7	Year 6
Fractions: Multiplication with fractions	Year 7-9	Year 6	Year 6	Year 8-9 (implicit)	8-11	Year 7
Fractions: Division by whole numbers	Year 7-9	No reference	Year 6	No reference	Year 5-7	No reference
Fractions: Division with fractions	Year 7-9	Year 6	Year 8	Year 8-9 (implicit)	Year 8-11	Year 7
Decimals: Introduction of addition and subtraction	Year 3-6	Year 6	Year 4 (in context of money)	Year 2-7 (simple decimals)	Year 5-7	Year 6 (with whole numbers)
Decimals: Addition and subtraction of numbers to 2 decimal places	Year 7-9 (Level 5 Attainment Target, 2007)	Year 6	Year 5	Year 8-9 (implicit)	Year 5-7	Year 8 (implicit)
Decimals: Multiplication & division by multiples of 10 or whole numbers	Year 3-6	Year 6 (multi'n) Year 7 (division)	Year 5 (in context of money)	Year 2-7	Year 5-7	Year 5
Decimals: Multiplication & division of numbers to 2 decimal places	Year 7-9 (Level 5 Attainment Target, 2007)	Year 6 (multi'n) Year 7 (division)	Year 8 (implicit)	Year 8-9 (implicit)	Year 8-11 (implicit)	Year 8 (implicit)

Table 4.6: Example of addition and subtraction of fractions in England (1999, 2007), Hong Kong (2000) and Singapore (2001)

	England (1999, 2007)	**Hong Kong (2000)**	**Singapore (2001)**
Addition and subtraction of fractions with like denominators	**Year 7-9** Arithmetic and fractions not included in primary National Curriculum (1999) Rules of arithmetic applied to calculations and manipulations with rational numbers (2007) *Attainment Targets:* [Pupils] add and subtract fractions by writing them with a common denominator (Level 6 Attainment Target –national expectation at end of Year 9)	**Year 5** Add and subtract fractions with the same denominators and reduce the answers to the simplest form	**Year 3-5** **Year 3 - fractions within one whole** Very basic addition and subtraction in context of interpretation of a fraction as a whole: 'addition and subtraction of like fractions within one whole Denominators of given fractions should not exceed 12 **Year 4 - Related fractions within one whole** Addition and subtraction of two related fractions within one whole - Denominators of given fractions should not exceed 12 **Year 5 - like fractions and related fractions** Addition and subtraction of like fractions and related fractions - denominators of given fractions should not exceed 12; exclude calculations involving more than 2 different denominators
Addition and subtraction of fractions using unlike denominators	**Year 7-9** See above	**Year 6** Perform addition and subtraction of simple fractions with different denominators for sums involving at most two operations; solve problems involving addition and subtraction of simple fractions. Denominators involved should not exceed 12	No reference

Shape, space and measure

As with other domains, where content is sufficiently comparable, it appears that broadly the same content is covered in all curricula. The differences again lie in the way the curriculum is broken down and sequenced. For example, it was found that in the sub-domain of *geometry* and *measure*, there is a great degree of variation in the way in which content is specified. This is particularly true when comparing the secondary curricula.

An example of this can be seen in relation to the knowledge and application of properties of shapes and Pythagoras' theorem. Some curricula simply list shapes, properties and proofs (e.g. Singapore and Finland); others provide specific detail about how knowledge and proofs should be applied (e.g. England 1999); and some present a mix of detailed and less detailed content (e.g. Hong Kong).

Another example is how transformational geometry is specified. Although transformational geometry is included in all jurisdictions to some extent, some only cover this in primary (Flemish Belgium and Finland) and others only in secondary (Hong Kong and Singapore), while there is a stronger overall emphasis in England that is not found in the other jurisdictions. This is supported by findings in Ruddock and Sainsbury, 2008[99]. Notably, the most recent revision to the Singapore curriculum in 2007 has removed references to transformational geometry in the express curriculum route (completed by the majority of pupils in Singapore). However, it is still present in the technical curriculum route.

Area

In the context of *area* further differences can be found, particularly in relation to calculating areas using an appropriate formula (see Table 4.7 below). It can be seen that Hong Kong, Singapore and Massachusetts all have higher expectations with regard to understanding the area of squares, rectangles and triangles – around Years 4-6.

Table 4.7: Sequence of area across jurisdictions

	England (1999; 2007)	**Singapore (2001)**	**Hong Kong (2000)**	**Flemish Belgium (2010)**	**Finland (2004)**	**Mass. (2000; 2004)**
Introduction of area[100]	Years 3-6	Year 4	Year 5	Year 2-7	Year 3-4	Year 2-5
Squares & rectangles - Inc. calculating with formula	Year 3-6 (Level 5 Attainment Target, 2007)	Year 4	Year 5	Year 8-9	No reference	Year 6
Triangles – Inc. calculating with formula	Year 7-9	Year 6	Year 6	Year 8-9	Year 5-7	Year 6
Other shapes – Inc. calculating with formula	Year 7-9 (parall'ms, composite shapes and circles)	Year 8 (parall'ms, trapezia, composite shapes and circles)	Year 6 (parall'ms, trapezia and other polygons) Year 8-10 (circles)	Year 8-9 (circles)	Year 5-7 (parall'ms) Year 8-11 (circles and other plane figures)	Year 7 (parall'ms and composite shapes) Year 8 (trapezia and circles)

As highlighted earlier in relation to multiplication and area, calculating rectangular areas is not the national expectation at the end of Year 6 in

[99] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.
[100] For example, understanding of area in concrete terms; counting squares; units of area.

England. Instead, it is only specified as a desirable outcome for those pupils working above the national expectation. Similarly, introducing the area of a circle is the expectation in Year 8 in Singapore and Massachusetts while the national expectation in England is at the end of Year 9. Table 4.8 provides a more detailed example of the level of expectation in this sub-domain between England and Hong Kong.

Table 4.8: Example of difference in level of demand of calculations of area with formulae in England (1999, 2007) and Hong Kong (2000)

	England (1999, 2007)	Hong Kong (2000)
Squares & rectangles	**Year 3-6** Find areas of *rectangles* using the formula, understanding the connection to counting squares and how it extends this approach *Attainment Targets:* Find areas by counting squares (Level 4 Attainment Target 2007 - national expectation at end of Year 6) Pupils understand and use the formula for the area of a rectangle' (Level 5 Attainment Target 2007 - above national expectation at end of Year 6)	**Year 5** Understand and apply the formulae for calculating the area of squares and rectangles
Triangles	**Year 7-9** Use their knowledge of rectangles, parallelograms and triangles to deduce formulae for the area of a parallelogram, and a triangle, from the formula of a rectangle Calculate perimeters and areas of shapes made from triangles and rectangles *Attainment Targets:* [Pupils] understand and use appropriate formulae for finding circumferences and areas of circles, areas of plane rectilinear figures (Level 6 Attainment Target 2007 - national expectation at end of Year 9)	**Year 6** Understand and apply the formulae for finding the area of parallelograms, triangles and trapeziums.
Other shapes	**Year 7-9** **Parallelograms, composite shapes and circles** Use their knowledge of rectangles, parallelograms and triangles to deduce formulae for the area of a parallelogram, and a triangle, from the formula of a rectangle Recall and use the formulae for the area of a parallelogram and a triangle Calculate perimeters and areas of shapes made from triangles and rectangles Find […] areas enclosed by circles, recalling relevant formulae *Attainment Targets:* [Pupils] understand and use appropriate formulae for finding circumferences and areas of circles, areas of plane rectilinear figures…(Level 6 Attainment Target 2007 - national expectation at end of Year 9)	**Year 6** **Parallelograms, trapezia and polygons** Understand and apply the formulae for finding the area of parallelograms, triangles and trapeziums Find the area of polygons **Year 8-10** **Circles** Explore the formula for the area of a circle Calculate circumferences and areas of circles

Volume
In relation to *volume*, the picture is similar. Hong Kong, Singapore and Massachusetts appear to have the highest expectations (see Table 4.9). For example, they all introduce the concept of measuring volume (e.g. counting cubes) and how to calculate volume around Year 4-7. England, and indeed Finland and Flemish Belgium, set expectations from Year 7 or 8 onwards. Table 4.10 provides a more detailed example of the level of expectation in this sub-domain between England, Hong Kong and Singapore.

Table 4.9: Sequence of volume calculations across jurisdictions

	England (1999, 2007)	Singapore (2001)	Hong Kong (1999, 2000)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000, 2004)
Measuring volume (e.g.. counting cubes)	Year 7-9	Year 5	Year 7	No reference	No reference	Year 4-5
Volume of cubes and cuboids	Year 7-9 (Level 6 Attainment Target, 2007)	Year 5	Year 6	Year 8-9	Year 8-11	Year 6
Volume of prisms, pyramids, cylinders, cones and spheres	Year 7-9 (right prisms – (Level 7 Attainment Target, 2007) Year 10-11 (other shapes)	Year 8 (prisms & cylinders) Year 9 (other shapes)	Year 8-10	No reference	No reference	Year 8 (prisms & cylinders) Year 10-11 (cones and spheres)

Table 4.10: Example of difference in level of demand of calculations of volume with formula in England (1999, 2007), Hong Kong (1999, 2000) and Singapore (2001)

	England (1999, 2007 where stated)	Hong Kong (1999, 2000)	Singapore (2001)
Cubes/ cuboids	**Year 7-9** Find volumes of cuboids, recalling the formula and understanding the connection to counting cubes and how it extends this approach *Attainment Targets:* [Pupils] understand and use appropriate formulae for finding… volumes of cuboids when solving problems ((Level 6 Attainment Target 2007 - national expectation at end of Year 9)	**Year 6** Use formula to find volume of a cuboid Use formula to find volume of liquid in a rectangular container	**Year 5** Understand and apply the formula for finding the volume of cube and cuboids
Other solids	**Year 7-9** **Prisms:** Volumes of right prisms *Attainment Targets:* [Pupils] calculate lengths… volumes in… right prisms (Level 7 Attainment Target 2007 – above national expectation at end of Year 9) **Year 10-11** **Pyramids, cylinders, cones & spheres:** Solve problems involving surface areas and volumes of prisms, pyramids, cylinders, cones and spheres; solve problems involving more complex shapes and solids, including segments of circles and frustums of cones *Attainment Targets:* Calculate… volumes of cones and spheres' (Exceptional performance Attainment Target 2007)	**Year 8-10** **Pyramids, cones and spheres:** Understand and use the formulas for volumes of pyramids, circular cones and spheres	**Year 8** **Prisms and cylinders:** Find volume and surface area of cubes, cuboids, prisms and cylinders **Year 9** **Pyramids, cones and spheres:** Find volume and surface area of spheres, pyramids and cones

Algebra

The majority of comparator jurisdictions cover the same algebraic curriculum content at the same time. However, Hong Kong and Singapore have higher expectations in primary and secondary respectively. In addition, a study conducted by NFER[101] found that England had a particular weakness in algebra, including simple algebraic manipulation. In Table 4.11, three aspects of the *algebra* curriculum are compared across England, Hong Kong and Singapore curricula (see also Appendix B, Table B5).

Interestingly the level of expectation between Singapore and Hong Kong in algebra differs significantly across primary and secondary. For example, Hong Kong is unique in expecting pupils to be introduced to solving simple

[101] Ruddock, G. Clausen-May, T. Purple, C. and Ager, R. (2006). *Validation Study of the PISA 2000, PISA 2003 and TIMSS 2003 International Studies of Pupil Attainment.* (p123) DfES Research Report RR772.

equations in Year 6. The majority of high-performing jurisdictions introduce letters to symbolise an unknown but specific number (e.g. missing number problems). Singapore and Flemish Belgium do not introduce algebraic notation until Year 7.

While Singapore's curriculum up to Year 6 appears to be one of the least challenging in terms of algebraic content, Singapore is by far the most challenging in secondary in that it covers significantly more demanding content at an earlier stage. This key difference in expectation is apparent in the content sub-domain of quadratic equations, which is first covered substantially in Year 9 (see Table 4.11). By contrast, most of the other comparator jurisdictions do not introduce quadratic equations until Year 10-11. Massachusetts is the exception, introducing the concept from Year 8 through the use of tables and graphs. The expectation is that problems with quadratic equations are solved numerically or graphically through the use of technology. Analytic approaches to quadratic equations are introduced from Year 10.

Table 4.11: Sequence of algebra sub-domains in England (1999, 2007), Hong Kong (2000), and Singapore (2001)

	England NC (1999, 2007 where stated)	**Hong Kong (2000)**	**Singapore (2001)**
Introduction to algebra	**Year 3-6 (Key Stage 2)** Recognise, represent and interpret simple number relationships, constructing and using formulae in words then symbols [for example, c = 15 n is the cost, in pence, of n articles of 15p each] *Attainment Targets:* Begin to use simple formulae expressed in words (Level 4 Attainment Target 2007 - national expectation at end Year 6) Construct, express in symbolic form, and use simple formulae involving one or two operations (Level 5 Attainment Target 2007 – above national expectation at end Year 6)	**Year 6** Use symbols or letters to represent numbers	**Year 7** Use a letter to represent an unknown number and write a simple algebraic expression in one variable for a given situation Simplify algebraic expressions Evaluate simple algebraic expressions by substitution Solve word problems involving algebraic expressions
Introduction to linear equations	**Year 7-9** Solve linear equations, with integer coefficients, in which the unknown appears on either side or on both sides of the equation; solve linear equations that require prior simplification of brackets, including those that have negative signs occurring anywhere in the equation, and those with a negative	**Year 6** Solve simple equations involving one step in the solutions and check the answers (involving whole numbers only)	**Year 8** Solve simple linear equations - include simple cases involving fractional and decimal coefficients

	England NC (1999, 2007 where stated)	Hong Kong (2000)	Singapore (2001)
	solution (1999) Linear equations - includes setting up equations, including inequalities and simultaneous equations. Pupils should be able to recognise equations with no solutions or an infinite number of solutions (2007) *Attainment Targets:* [Pupils] formulate and solve linear equations with whole-number coefficients (Level 6 Attainment Target 2007 - national expectation at end Year 9) They use algebraic and graphical methods to solve simultaneous linear equations in two variables (Level 7 Attainment Target 2007) They manipulate algebraic formulae, equations and expressions, finding common factors and multiplying two linear expressions (Level 8 Attainment Target 2007)		

	England NC (1999, 2007 where stated)	Hong Kong (2000)	Singapore (2001)
Introduction of quadratic equations	**Year 10-11** Factorisation; completing the square; using the quadratic formula; simultaneous equations with one quadratic (1999) Linear, quadratic and other expressions and equations – includes relationships between solutions found using algebraic or graphical representations and trial and improvement methods. Simultaneous equations should include one linear and one quadratic equation (2007) *Attainment Targets:* [Pupils] sketch and interpret graphs of linear, quadratic, cubic and reciprocal functions, and graphs that model real situations (Level 8 Attainment Target, 2007) Solve simultaneous equations in two variables where one equation is linear and the other is quadratic (Level 8/exceptional performance)	**Year 11-12** Quadratic equations in one unknown; graphical methods	**Year 9** Solving quadratic equations in one unknown; factorisation; special products; simple quadratic algebraic fractions; addition and subtraction of algebraic fractions with quadratic denominators **Year 10-11** Solving quadratic equations in one unknown using formula; completing the square; solving fractional quadratic equations

Data, statistics and probability

Data and statistics

The introduction of *data and statistics* varies significantly across jurisdictions. Hong Kong, Singapore, Massachusetts and England introduce in early primary and gradually develop throughout the primary and secondary stages. However, at primary level, England appears to cover a broader range of sub-domains within *data handling* which would suggest that the National Curriculum in England is more demanding than Hong Kong and Singapore. See Table 4.12 for an overview of a number of key representations and concepts within *data and statistics*.

Table 4.12: Overview of sequence of sub-domains in data and statistics

	England (1999)	Singapore (2001)	Hong Kong (1999, 2000)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000, 2004)
Simple data handling & interpret-ation[102]	Year 1-2 (simple lists, tables and charts) Year 3-6 (discrete & continuous data)	Year 2 (pictograms) Year 3-6 (block & line graphs)	Year 3 (pictograms) Year4-6 (block graphs, bar charts)	Year 8-9	Year 3-4 (simple tables, diagrams, bar graphs)	Year 4
Measures of central tendency	Year 3-6 (mode) Year7-9 (mean, median)	Year 9	Year 8-10 (mean, median, mode)	Year 10-11 (mode, mean)	Year 5-7	Year 6
Standard deviation – statistical measures of spread or variability	Year 7-9 (distribution) Year10-11 Higher tier (spread)	Year 10-11	Year 11-12	Post-16	Year 8-11 (Finland use the term dispersion)	Year 9
Quartiles and inter-quartile range	Year 10-11 Higher tier	Year 10-11	Year 11-12	After Year 11	After Year 11	After Year 11

From Year 1, England sets high expectations in relation to *data collection* and *data display* earlier, with a wider repertoire of methods, than other jurisdictions. This is reflected in the findings from Ruddock and Sainsbury (2008)[103]. As Table 4.12 shows, the National Curriculum covers concepts such as discrete and continuous data and mode from Year 3 and later sets expectation on measures of central tendency (averages) and measures of spread relatively early compared to the other jurisdictions. Table 4.13 illustrates the differences in levels of expectation between England, Hong Kong and Singapore in these areas.

Table 4.13: Example of difference in level of demand within data and statistics in England (1999,2007), Hong Kong (1999) and Singapore (2001)

	England (1999, 2007)	Hong Kong (1999)	Singapore (2001)
Measures of central tenancy	**Year 3-6** **Mean** Know that mode is a measure of average **Year 7-9** **Mode and median** Identify the modal class for grouped data Find the median for large data sets	**Year 8-10** Discuss the relative merits of different measures of central tendency for a given situation	**Year 9** Find mean, median and mode; distinguish between the purposes for which mean, median and mode are used

102 Includes collecting, classifying, organising data; constructing and interpreting simple tables, diagrams and graphs.
103 Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.

	England (1999, 2007)	Hong Kong (1999)	Singapore (2001)
	and calculate an estimate of the mean for large data sets with grouped data *Attainment Targets* Pupils understand and use the mean of discrete data. They compare two simple distributions using the range and one of the mode, median or mean (Level 5 Attainment Target 2007 - national expectation at end Year 9) They determine the modal class and estimate the mean, median and range of sets of grouped data, selecting the statistic most appropriate to their line of enquiry (Level 7 Attainment Target 2007)		
Measures of spread	**Year 7-9** Compare distributions and make inferences, using the shapes of distributions measures of central tendency and spread (2007) **Year 10-11 - Higher tier** Compare distributions and make inferences, using shapes of distributions and measures of average and spread, including median and quartiles; understand frequency density	**Year 11-12** Recognize range, inter-quartile range and standard deviation as measures of dispersion for a set of data	No references to measures of spread

Probability

The majority of the high-performing jurisdictions including Hong Kong, Singapore and Flemish Belgium do not expect *probability* to be introduced until between Year 8 and 10. By contrast, England expects pupils to be introduced to the concept from Year 3 while in Finland the expectation is from Year 5. Table 4.14 provides an overview of four concepts that are part of probability across the comparator jurisdictions.

Table 4.14: Overview of sequence of sub-domains within probability

	England (1999, 2007)	Singapore (2001)	Hong Kong (1999)	Flemish Belgium (2010)	Finland (2004)	Mass. (2000, 2004)
Introduction (e.g. via simple experiments; related vocabulary)	Years 3-6	Years 10-11	Years 8-10	Years 10-11 (implicit)	Years 5-7	Years 3-4
Simple experimental probability	Years 7- 9	No reference	Years 8-10	Years 10-11	Years 8-11	Years 5-6
Equally likely outcomes	Years 7- 9	Years 10-11	Years 8-10	No reference	No reference	No reference
Mutually exclusive events	Years 7- 9 (Level 7 Attainment Target, 2007)	Years 10-11	Years 10-11 (extension)	No reference	No reference	No reference

The broad conclusion seems to be that the England National Curriculum sets higher expectations covering a wider range of *probability* concepts than some other jurisdictions such as Flemish Belgium, Finland and Massachusetts. Moreover, concepts such as equally likely outcomes and mutually exclusive events are expected earlier in England than in the curricula of Singapore and Hong Kong. Table 4.15 illustrates difference in level of expectation between England and Singapore in these areas.

Table 4.15: Example of probability in England (1999, 2007) and Singapore (2001)

	England (1999, 2007)	Singapore (2001)
Theoretical & experimental probability	**Year 7-9** Understand and use the probability scale; understand and use estimates or measures of probability from theoretical models, relative frequency; list all outcomes for single events, and for two successive events, in a systematic way**;** know that the sum of the probabilities of all these outcomes is 1 Experimental and theoretical probabilities, including those based on equally likely outcomes (2007) *Attainment Targets:* When solving problems, [pupils] use their knowledge that the total probability of all the mutually exclusive outcomes of an experiment is 1 (Level 6 Attainment Target 2007) They understand relative frequency as an estimate of probability and use this to compare outcomes of experiments (Level 7 Attainment Target 2007 - national expectation at end Year 9)	**Year 10-11** Calculate the probability of a single event as either a fraction or a decimal (not a ratio); calculate the probability of simple combined events, using possibility diagrams and tree diagrams where appropriate (in possibility diagrams outcomes will be represented by points on a grid and in tree diagrams outcomes will be written at the end of branches and probabilities by the side of the branches) No reference to experimental probability

Section 5 – Curriculum comparisons for science

5.1 Introduction

This section first sets out the selection of five comparator jurisdictions based on the findings of the international comparison studies, followed by the initial findings from the content analysis of the science curricula in five high-performing jurisdictions and the science National Curriculum for England. The jurisdictions are: Alberta, Canada; Hong Kong; Massachusetts, USA; Singapore; and Victoria, Australia[104].

As with English and mathematics, the purpose of comparing the curricula has been to identify whether there are any similarities and differences between the curricula which could be used to inform the development of the National Curriculum in England. The content analysis focuses on the level of the statutory curricula for science in high-performing jurisdictions compared to the 1999 and 2007[105] National Curricula for England. As stated in Section 1.3, the analysis does not include wider non-statutory guidance and other related resources. For this reason, the secondary Science Framework and related resources introduced as part of the National Strategies are not within the scope of this analysis.

The focus has been on the organisation, breadth, specificity and, where possible, the level of challenge and sequencing of content within comparable age-phases (see Appendix C for more detail). The analysis examines the aims and domains common to the science curricula in the different jurisdictions.

A number of examples are provided showing key differences between the National Curriculum and the statutory curricula of high-performing jurisdictions, focusing in particular on where the content in high-performing jurisdictions appears to be more challenging than in England. These are intended to illustrate where the new National Curriculum for science could be strengthened so that the content, standards and expectations are on a par with the highest-performing jurisdictions.

5.2 Key findings

- Despite variation in terms of structure and approach, curricula reviewed largely cover the same ground in terms of the key domains of *biology*, *chemistry* and *physics*. Whilst they are not usually presented as separate science disciplines, the content is identifiable under these headings.

- *Earth and space science* is also covered across all the curricula analysed, but is only presented as a separate discipline in Alberta and

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[104] The Victoria science curriculum 2008 was only analysed in relation to scientific processes and enquiry.
[105] For brevity, reference is made to the 2007 National Curriculum for secondary science even through Key Stage 4 was first published in 2005 and Key Stage 3 was subsequently published in 2007.

Massachusetts. The curricula reviewed also cover the same ground in terms of the key concepts and knowledge within the domains of *biology*, *chemistry* and *physics*. None of the curricula reviewed sacrifice breadth for depth in terms of coverage.

- All curricula reviewed emphasise the importance of *scientific processes* and *scientific enquiry* at both primary and secondary and the coverage is broadly similar across the jurisdictions analysed.

- The curricula reviewed differ in the level of specificity of the statements: England (2007) has the highest level generic statements; England (1999), Hong Kong and Massachusetts have medium level specificity; and Singapore and Alberta have statements at the highest level of specificity.

- The level of challenge in England seems to be broadly similar to the high-performing jurisdictions analysed, in terms of when content is introduced and when key knowledge and concepts are covered. Singapore and Alberta seem more challenging in places, but this could be a reflection of their high level of specificity.

5.3 Selecting comparator jurisdictions

The curriculum analysis first involved the selection of a small number of high-performing jurisdictions in science to benchmark against England. Identifying comparator jurisdictions was in part based on a synthesis of the results from these international comparisons and also on whether an education system for the given jurisdiction is organised at a national or sub-national (state, province, region) level. Given this, it was sometimes necessary to draw on other studies to identify regions with the highest performing pupils within a particular nation. The jurisdictions covered in each survey are set out in Table 5.1.

Table 5.1: Jurisdictions covered in recent waves of PISA and TIMSS

		Australia	Alberta	Flemish Belgium	Finland	Hong Kong	Massachusetts	New Zealand	Shanghai	Singapore
Science	TIMSS 2007 *age 10*	☑	☑			☑	☑	☑		☑
	TIMSS 2007 *age 14*	☑				☑	☑			☑
	PISA 2006 *age 15*	☑	☑ (Can.)	☑ (Belg.)	☑	☑	☑ (USA)	☑		

In the fourth grade TIMSS 2007 science tests, when pupils were at least 9.5 years old, Singapore was the highest-scoring education system, with an average score of 587. The second and third highest-performing education systems were Massachusetts (571) and Chinese Taipei (557). England achieved an average score of 542, which was significantly higher than the scale average of 500.

For eighth grade science, when pupils were at least 13.5 years old, the highest-performing education system was Singapore with an average scale score of 567. The second and third highest scores were recorded by Chinese Taipei (561) and Massachusetts (556). England achieved an average score of 542 (coincidentally the same score as the age 10 tests), which was significantly higher than the TIMSS scale average of 500[106].

The highest-scoring jurisdictions in the 2009 PISA age 15 science tests were Shanghai (575), followed by Finland (554) and Hong Kong (549) [107]. Australia (527) and England (515) both scored higher than the OECD average (501) at a statistically significant level.

Alberta is included as results from the PISA 2000 study showed that Alberta was the highest-performing Canadian province in science, while Canada as a whole out-performed England in the PISA 2009 study in science. Victoria is included as national tests of 12 year olds in 2009 showed Victoria was the second highest-performing Australian state in scientific literacy[108], while Australia as a whole out-performed England in the PISA 2009 study in science[109].

Among all the jurisdictions taking part in the above studies, it is possible to identify five jurisdictions with the highest achieving pupils in science. The selected jurisdictions are:

- Alberta, Canada;
- Hong Kong;
- Massachusetts, USA;
- Singapore; and
- Victoria, Australia.

5.4 Curriculum analysis for science – an overview

The purpose of the content analysis is to draw out key similarities and differences in the breadth, the level of specificity and – where possible – the level of challenge and sequencing. Although not every domain or sub-domain of science is examined, the analysis is intended to give a clear indication of how the curricula vary and what can be learned from high-performing jurisdictions.

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[106] Martin, M.O. Mullis, I.V.S. and Foy, P. (with Olson, J.F. Erberber, E. Preuschoff, C. and Galia, J.) (2008). *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

[107] OECD (2010a). *PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I)*. Paris, OECD Publishing.

[108] The Australian Capital Territory (ACT) was the highest performing but was excluded due to the unique and very small nature of this jurisdiction. The survey results are published in by the Australian Curriculum, Assessment and Reporting Authority (2010) *National Assessment Program – Science Literacy Year 6 Report 2009*, ACARA: Australia.
http://www.nap.edu.au/_Documents/MCEECDYA/2009%20NAP%20SL%20Public%20report.pdf

[109] Bradshaw, J. Ager, R. Burge, B. and Wheater, R. (2010). *PISA 2009: Achievement of 15-Year-Olds in England.* Slough: NFER.

Breadth

Despite variation in how the curricula are organised and presented, the analysis has shown that there is a commonality in terms of the coverage of the domains of science. The analysis also demonstrates that all the curricula reviewed largely cover the same content within the domains of science – in other words the key concepts, knowledge and processes are broadly similar across all the curricula analysed. Therefore none of those reviewed sacrifice breadth for depth.

All the jurisdictions analysed organise their curriculum around the key domains of *biology, chemistry and physics,* although they are not usually presented under these headings. At primary, most jurisdictions, including England, offer general science, with the exception of Hong Kong where science is taught as a unit within General Studies; and Massachusetts, where science is broken down into *earth and space science, life sciences, physical sciences*; and *technology and engineering*.

At secondary, most of the jurisdictions analysed do not separate the sciences, but it is possible to distinguish the content as *biology*, *chemistry* and *physics*. Massachusetts organise their content into separate disciplines across secondary, although *physical science* is not separated out into *chemistry* and *physics* until upper secondary.

- ***England:*** General science from primary to the end of secondary; although pupils can study separate sciences (*biology*, *chemistry* and *physics*) to GCSE level in Years 10 and 11. Both the1999 and 2007 National Curricula are set out in domains that are related to the disciplines of *biology*, *chemistry* and *physics*. Design and technology is specified as a stand-alone subject, separate from science.

- ***Alberta:*** General science from primary to the equivalent of Year 11, although the content is set out in domains that are largely related to the disciplines of *biology*, *chemistry* and *physics*.

- ***Massachusetts:*** *Earth and space science, life sciences, physical sciences*; and *technology and engineering* from primary to end of junior secondary; and *physical sciences* are then separated into *chemistry* and *physics* in senior secondary.

- ***Hong Kong:*** Primary science is a unit within general studies; and at secondary it is titled General Science. The content is set out in domains that are related to the disciplines of *biology*, *chemistry* and *physics*.

- ***Singapore:*** General science in both primary and secondary, although in secondary separate qualifications (O-levels) are available in *biology*, *chemistry* and *physics*. Again, the content is set out in domains that are related to the disciplines of *biology*, *chemistry* and *physics*.

- ***Victoria*[110]*:*** General science covering *biology*, *chemistry*, *earth science*, *environmental science*, *health sciences*, *neuroscience*, *physics* and *space sciences* and emerging sciences such as *biotechnology*. A strong theme on *scientific enquiry* is embedded within the programme content and also expressed as a separate set of learning standards under the heading *science at work*.

The analysis also suggests that there is a commonality of core content within the science domains of *biology*, *chemistry* and *physics*. Across the curricula analysed, coverage of the key concepts and knowledge seems broadly comparable:

- ***Biology:*** All cover *plants and animals*, including *humans*; *structure and function*; *interactions and interdependencies; energy*; and *evolution*;

- ***Chemistry:*** All cover the *nature of matter and energy*; *physical change*; *chemical change*; and *properties of materials*; and

- ***Physics:*** All cover *forces and motion*, *light, sound and waves*, *electricity and magnetism*, *energy and matter*, and *the earth and universe*.

All the curricula analysed also include *scientific processes and enquiry* at both primary and lower secondary level which commonly include:

- ***At primary:*** Designing, carrying out and interpreting the findings of scientific investigations;

- ***At lower secondary:*** Reflecting critically on the nature of scientific explanation, theory, models and their relationship to scientific evidence; framing hypotheses and research questions; designing and carrying out investigations and experiments; using established scientific equipment and techniques; recording, presenting and interpreting scientific data; interpreting data and findings with reference to hypotheses and conclusions; using scientific language and terminology; and suggesting improvements to methods.

Specificity

The analysis of comparator jurisdictions showed significant variation across the documents reviewed in terms of the level of detail provided. The analysis also showed significant variation in terms of how the science curricula are expressed, with most focus on learning outcomes.

- ***England:*** Content is expressed in terms of what pupils should be

[110] The main interest in Victoria (2008) relates to the highly specified treatment of scientific enquiry while the content specification was much more general. The analysis therefore only focused on scientific enquiry.

taught; with Attainment Targets defining the standard expected. The 2007 National Curriculum for secondary retains the Attainment Targets but sets out the content as key target concepts that pupils should be able to understand;

- ***Hong Kong:*** The science curriculum is expressed in term both of what pupils should learn and of what they should be able to do;

- ***Singapore:*** The science curriculum sets out very detailed learning outcomes;

- ***Alberta:*** A general overview of the content is provided, with the detail of the subject content expressed as learning outcomes; and

- ***Massachusetts:*** The content is set out as learning standards alongside some explanatory notes for developing the content.

The National Curriculum for England (1999) has broad statements about what should be taught and summarises the standard that is expected in terms of level descriptors. England (2007) sets out very high level generic statements about what students should be taught. For both, the content is set out in age bands of two to four year age-phases.

The Hong Kong primary framework for general studies, which includes science, sets out the core elements of the subject and learning objectives in broad statements. At lower secondary the curriculum has much more detailed statements setting out what pupils should learn and what they should be able to do. Content is set out over three year age phases. The Massachusetts framework sets out broad concept statements but includes more detail alongside this by way of explanatory notes and is set out in three year blocks. Both of these curricula are comparable to England 1999 in terms of specificity.

The curriculum in Singapore is very detailed in comparison with others. Domains and sub-domains are broken-down and coverage explained to a high level of specification. Content is set out on a year-on-year basis for lower secondary. Alberta is comparable here, with domains and sub-domains set out at various levels of specificity. For example, an overview of the domain is provided, then some focusing questions, then the key concepts covered in the domain and then the outcomes expected in detail. Content is also expressed on a year-on-year basis. Both these curricula are more detailed than England 1999 or 2007.

Challenge

Level of challenge has been analysed in terms of when content is introduced and when key concepts are covered. Despite limitations noted elsewhere in relation to mapping age-phases (see Section 1.3), our analysis seems broadly in line with that carried out by Ruddock and Sainsbury (2008) in their report of the primary curriculum[111]. Their analysis suggests that overall the primary science curriculum for Hong Kong is both narrower and less demanding than the curriculum for England (1999). The content of the Singapore primary curriculum on the other hand is broadly similar to the curriculum for England (1999), but slightly more demanding in some respects e.g. *life sciences* and *physics*. These findings are consistent with our analyses.

At secondary, Table C7 (Appendix C) sets out arrangements at Years 10-11 and demonstrates that these are not directly comparable across the jurisdictions. Whilst science is largely compulsory at Years 7-9 or equivalent[112], upper secondary science tends to be elective (or have elective units) and is a foundation for the A level equivalent. Therefore at secondary level, it is only at Years 7-9 where fair comparisons can be drawn. However, given that the international tests PISA and TIMSS are conducted at age 15 and 14 years respectively, the Year 7-9 curriculum has high relevance to pupil achievement in these studies.

For Hong Kong, the content at Years 7-9 was broadly in line with the previous 1999 National Curriculum for England, although there are examples where it is more challenging than England (e.g. in *chemistry*) and examples where it seems less challenging (e.g. in *biology*). This is interesting given that the Hong Kong curriculum is mapped against England in terms of slightly different key stages, so pupils in Hong Kong will be on average eight months older than English pupils in the comparable age-phases (see Section 1.3 for further explanation of the mapping used). For Singapore, the content at Years 7-9 seems broadly similar to the 1999 National Curriculum but slightly more demanding in some areas. However, the current 2007 England National Curriculum for secondary is not sufficiently specific to assess comparable levels of challenge.

The content in the Massachusetts and Alberta curricula seems broadly consistent with the 1999 England National Curriculum in terms of coverage of topics and concepts and when they are introduced, including *scientific enquiry*, at both primary (Years 2-6) and lower secondary (Years 7-9). The Alberta curriculum is specified in much more detail so can appear more challenging. However it is difficult to assess whether this is actually more demanding in practice. Again, the current 2007 England National Curriculum for secondary is not sufficiently specific to assess comparable levels of challenge.

Analysis of *scientific enquiry* for primary and secondary suggests that the 1999 England National Curriculum seems to require more sophistication – in that there is a focus on pupils thinking critically and thinking for themselves (e.g. reflecting critically on experimental procedures and deciding for themselves what data to collect) than in Hong Kong and Singapore. However, for primary this conclusion is not supported by Ruddock and Sainsbury

[111] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.
[112] In Singapore, around 85% of students follow the ‘normal academic’ route while around 15% follow the ‘normal technical’ route.

(2008), who suggest that *scientific enquiry* is broader in England than in Hong Kong and Singapore but is similar in terms of level of difficulty.

5.5 Curriculum aims

All curricula analysed have a clear set of curriculum aims for science (see Appendix C, Table C1). All emphasise the importance of encouraging pupils' curiosity about the world around them at primary. They all also take a broadly constructivist approach to science at primary as building on their existing knowledge and understanding. Some curricula have overarching aims for primary and secondary science, whilst others have separate but related aims for primary and secondary.

All jurisdictions emphasise the importance in the science curriculum of developing knowledge in the fundamental concepts and knowledge of science. They all also stress the central importance of the processes needed in science – observation, investigation, experimentation, measurement, theory-building and problem solving. For example, the Singapore curriculum suggests that it is not possible to know and understand all scientific knowledge in a rapidly changing technological world; therefore it is important to develop scientific literacy and give pupils the skills and attitudes for scientific enquiry.

Taken together, these can be grouped into three overarching aims:

- increasing scientific knowledge through the inter-related disciplines of *biology*, *chemistry* and *physics* – including concepts and principles;
- applying the processes and methods of science through practical activity – such as observation and measurement;
- developing an understanding of *scientific enquiry* – the relationship between empirical evidence, scientific theory and explanation.

In terms of the overall purpose of science, most though not all refer to preparation for further study and ensuring that pupils become scientifically informed and responsible adults.

5.6 Scientific processes and enquiry

Science education in England and elsewhere has always required that pupils should learn about the processes through which scientific theory and knowledge advances, as well as being taught the concepts and theories that make up the substantive content of science. Science is a practical subject, in which pupils carry out investigations, analyse the data they collect, draw conclusions from it and relate their empirical evidence to theories and hypotheses. Traditional science education integrated these elements into their syllabi through a 'piecemeal process of accretion'[113]. Research has shown

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[113] Osborne J., Collins, S., Ratcliffe, M., Millar, R., and Duschl, R. (2003). *What "Ideas-about-Science" should be taught in school science? A Delphi study of the expert community.* Journal of Research in Science Teaching Vol. 40 No. 7 pp692-720

that there is a consensus among scientists and educators about the core processes that make up all forms of scientific enquiry[114] [115] [116] [117]. This consensus is reflected in the curriculum documents of other high-performing jurisdictions, as well as in the England National Curriculum. Curriculum aims for science within each jurisdiction are translated into more detailed specifications of particular kinds of scientific processes. These processes are commonly specified separately from the domains of *biology*, *chemistry* and *physics*.

Scientific literacy

More recently, the England National Curriculum for science was revised so that *scientific enquiry* at Key Stage 4 was embedded under the umbrella of a broader conceptual framework called 'How Science Works'. This development reflected an international shift in emphasis in science education, which had formerly been conceived of as providing foundational study for those who were to become the next generation of scientists. More recently, science courses have been focused in addition on providing a foundation in 'scientific literacy' for the general citizen[118]. The curricula of Singapore, Massachusetts and Alberta also refer explicitly to the importance of developing scientific literacy within science education. However, the England 2007 Programme of Study has been criticised for over-emphasising the social, cultural and philosophical aspects of science at the cost of failing to deliver secure coverage of the substantive content of science[119]. Most jurisdictions do nevertheless specify that science should be taught in the context of history of science and contemporary societal issues[120].

How scientific enquiry is reflected in curricula

The tables at Appendix C (Tables C5-C6[121]) provide an overview of the content for England and the five comparator jurisdictions in relation to scientific enquiry. At primary and lower secondary[122], overarching principles of

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[114] McComas, W.F. and Olson, J.K (1998). *The nature of science in international science education standards documents* in W.F. McComas (Ed) *The nature of science in science education: rationales and strategies* Dordrecht: Kluwer.
[115] Osborne J., Collins, S., Ratcliffe, M., Millar, R., and Duschl, R. (2003). *What "Ideas-about-Science" should be taught in school science? A Delphi study of the expert community.* Journal of Research in Science Teaching, Vol. 40 No. 7 pp692-720
[116] Schwartz, R. and Lederman N. (2008). *What scientists say: scientists' views of nature of science and relation to science context* International Journal of Science Education Vol. 30 No. 6 pp727-771.
[117] Eurydice (2006). *Science teaching in schools in Europe: policies and research.* last retrieved 16th December 2011 from http://www.mp.gov.rs/resursi/dokumenti/dok13-eng-Science_teaching.pdf
[118] Millar, R. (2006). *Twenty First Century Science: insights from the design and implementation of a scientific literacy approach in school science.* International Journal of Science Education Vol. 28 No. 13 pp1499-1521
[119] For example, see Shaha, A. (2009). *How science works isn't working in British schools*. New Scientist web article: http://www.newscientist.com/blogs/thesword/2009/12/how-science-works-isnt-working.html
[120] For example, see Eurydice (2006). *Science teaching in schools in Europe: policies and research.* last retrieved 16th December 2011 from http://www.mp.gov.rs/resursi/dokumenti/dok13-eng-Science_teaching.pdf
[121] Note that Singapore appears separately below the table as the way in which scientific enquiry was expressed in the Singapore curriculum could not be analysed this way.
[122] Lower secondary is largely Key Stage 3 equivalent but in some jurisdictions it cuts into the first part of KS4. Upper secondary is largely A level equivalent and late KS4.

scientific enquiry tend to be specified as separate statements within a broad general science curriculum. However, by upper secondary, all comparator curricula offer pupils an aptitude and preference-based choice of study of integrated/combined science or separate scientific disciplines. The content of *scientific enquiry* is then tailored to the specific route chosen.

All comparator curricula include aspects of *scientific enquiry* at both primary and lower secondary level (here equated to England's Years 7-9). This corresponds with the primary level findings of Sainsbury and Ruddock (2008) that compared the curricula of five countries (Singapore, Chinese Taipei, Hong Kong, Latvia and Ontario) with England. They concluded that the emphasis on *scientific enquiry* was shared by all other curricula, although not all include it as a separate element. With respect to *scientific enquiry*, they judged that the curricula of both Hong Kong and Singapore were similar in difficulty to that of England, but narrower in scope[123]. For the analysis in this report, the focus is on the core concepts of *scientific enquiry*. Therefore the scale of the difference noted by Ruddock and Sainsbury in the breadth of the primary *scientific enquiry* content will be less apparent.

Practical science

The TIMSS 2007 study found that *practical science* was a particular strength of England's science education[124]. Pupils in England had high levels of experience of practical work compared with pupils in other jurisdictions. The effect was particularly marked at age 10 but still apparent at age 14, by which stage most jurisdictions included a significant volume of practical work.

All the curricula analysed specify that at primary, pupils should be participating in designing, carrying out and interpreting the findings of scientific investigations. Most require younger primary school pupils to begin to explore the world through basic data, and all require older primary school children to begin to reflect on and use scientific explanation and relate it to empirical evidence. Most require even the youngest primary school children to begin to make predictions that they can test.

There are some examples where the curricula of high-performing jurisdictions seem more challenging than England at primary. For example, England, Massachusetts and Victoria all require primary school pupils to begin from the earliest age to ask questions about the world, and by around Year 3-6 to be able to suggest ways in which they might answer their questions by collecting evidence. In England, the expectation is couched in everyday language (ask questions; decide how to find answers; think about what might happen; try things out.) At this stage, Massachusetts is already introducing a more precise and rigorous description of scientific process (ask questions about objects, organisms and events; make predictions based on observed patterns;

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[123] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.
[124] Martin, M.O., Mullis, I.V.S., and Foy, P. (with Olson, J.F., Erberber, E., Preuschoff, C., & Galia, J((2008). *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College

make predictions that can be tested). Victoria requires pupils from Year 2-3 to use repeated observations to make predictions, and by Year 4-5 to see how the design of an experiment is directly related to the question asked. Therefore, Massachusetts and Victoria are introducing pupils to the idea that asking a scientific question is different from asking a day-to-day question – one that is based on previous observation of patterns and the formulation of specific predictions that can be tested (see Table 5.2).

Table 5.2: Example of scientific enquiry in lower primary: England (1999), Massachusetts (2001) and Victoria (2008)

England 1999 – Years 1-2	**Massachusetts 2001 – Reception to Year 3**	**Victoria 2008 Year 2-3**
Pupils should be taught: • To ask questions and decide how they might find answers to them. • To think about what might happen before deciding what to do.	• Ask questions about objects, organisms, and events in the environment. • Tell about why and what would happen if? • Make predictions based on observed patterns.	• Students begin to generate questions about situations and phenomena • They repeat observations over time to make predictions.*)*
England 1999 – Years 3-6	**Massachusetts 2001 – Years 4-6**	**Victoria 2008 Year 4-5**
Pupils should be taught: • To ask questions that can be investigated scientifically and decide how to find answers. • To think about what might happen or try things out when deciding what to do, what kind of evidence to collect, and what equipment and materials to use.	• Ask questions and make predictions that can be tested.	• They begin to understand that the design of experiments is directly related to their questions about things and events.

This also echoes a finding from Ruddock and Sainsbury (2008)[125] who judged that the Singapore curriculum element 'construct a hypothesis' did not have a direct correspondence in the England curriculum. The closest match - 'ask questions that can be investigated scientifically and decide how to find answers' – does not require application of scientific knowledge and understanding to develop a theoretical construct or question which may subsequently be tested through scientific enquiry.

Scientific theory and language

At lower secondary level, virtually all the curricula analysed – including England - require pupils to reflect critically on the nature of scientific explanation, theory, models and their relationship to scientific evidence. All require that pupils should participate actively in: framing hypotheses and research questions; designing and carrying out investigations and

[125] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to those of other high performing countries.* DCSF Research Report DCSF-RW048.

experiments; using established scientific equipment and techniques correctly, accurately, and with due regard to health and safety; recording, presenting and interpreting scientific data; and interpreting data and findings with reference to hypotheses and conclusions.

In addition, most jurisdictions specify that pupils should be using scientific language and terminology correctly, and be able to consider their investigation critically and to suggest improvements to methods or propose a further investigative stage.

Mathematics for science

Pupils need to have developed an appropriate level of mathematics to learn about and engage in particular science practice or theories. Analysis of how this is reflected in high-performing jurisdictions is still ongoing so is not reported here. However, an illustration of how this is achieved in the 1999 England National Curriculum is shown in Table 5.3. Inter-related content is identified but there is no explanation of how the two subjects link. It is also clear that the content and language could be aligned far more, in relation to understanding and using quantities (including standard units), representing data, data analysis techniques and using and understanding equations.

The analysis demonstrates that there is room for much greater alignment. Alignment is even less clear in the 2007 National Curricula for secondary. Table 5.4 shows that links have been made between the two subjects; for example: models are frequently expressed in the language of mathematics. However, there is no content beyond these high-level statements so it is difficult to establish the mathematical requirements for science.

Table 5.3: Programmes of Study for mathematics and science in the England 1999 National Curriculum

	Science National Curriculum (1999)	Mathematics National Curriculum (1999)
Years 1-2	**Present and communicate evidence** • communicate what happened in a variety of ways, including using ICT (e.g. in speech and writing, drawings, tables, block graphs and pictograms)	**Presentation of data using multiple/appropriate methods** • solve a relevant problem by using simple lists, tables and charts to sort, classify and organise information • discuss what they have done and explain their results
Years 3-6	**Using scientific judgement to design investigation** • make systematic observations and measurements, including the use of ICT for data logging	**Units of measure and conversion** • recognise the need for standard units of length, mass and capacity, choose which ones are suitable for a task, and use them to make sensible estimates in everyday situations; convert one metric unit to another (e.g. 3.17kg to 3170g); know the rough metric equivalents of imperial units still in daily use
Years 7-9	**Use diagrams to find, describe and explain relationships in data, draw conclusions from data and subsequently evaluate predictions** • use diagrams, tables, charts and graphs, including lines of best fit, to identify and describe patterns or relationships in data • use observations, measurements and other data to draw conclusions	**Interpret and discuss results. Interpret graphs, find patterns and anomalies, compare distributions using average and range, evaluate results, use correlation and lines of best fit** • relate summarised data to the initial questions • interpret a wide range of graphs and diagrams and draw conclusions • look at data to find patterns and exceptions • compare distributions and make inferences, using the shapes of distributions and measures of average and range • evaluate and check results, answer questions, and modify their approach if necessary • have a basic understanding of correlation • use lines of best fit
Years 10-11	**Understand the quantitative relationship between resistance, voltage and current**	**Use formulae in word and symbol form, substitute, derive and change subject** **(foundation)** • use formulae from mathematics and other subjects expressed initially in words and then using letters and symbols; substitute numbers into a

	Science National Curriculum (1999)	Mathematics National Curriculum (1999)
		formula; derive a formula and change its subject. **(higher)** • use formulae from mathematics and other subjects; substitute numbers into a formula; change the subject of a formula, including cases where the subject occurs twice, or where a power of the subject appears; generate a formula.

Table 5.4: Programmes of Study for mathematics and science in the 2007 National Curricula

	Science National Curriculum (2005, 2007)	Mathematics National Curriculum (2007)
Years 7-9	**Key Concepts** **Scientific thinking** • using scientific ideas and models to explain phenomena and developing them creatively to generate and test theories **Key Processes** **Critical understanding of evidence** Pupils should be able to: • obtain, record and analyse data from a wide range of primary and secondary sources, including ICT sources, and use their findings to provide evidence for scientific explanations • evaluate scientific evidence and working methods	**Key Concepts** **Critical understanding of evidence** • knowing that mathematics is essentially abstract and can be used to model, interpret or represent situations • recognising the limitations and scope of a model or representation. **Key Processes:** **2.3 Interpreting and evaluating** Pupils should be able to: • form convincing arguments based on findings and make general statements • consider the assumptions made and the appropriateness and accuracy of results and conclusions • be aware of the strength of empirical evidence and appreciate the difference between evidence and proof • look at data to find patterns and exceptions • relate findings to the original context, identifying whether they support or refute conjecture • engage with someone else's mathematical reasoning in the • context of a problem or particular situation • consider the effectiveness of alternative strategies.

	Science National Curriculum (2005, 2007)	Mathematics National Curriculum (2007)
Years 10-11	**How science works: Communication skills** Students should be able to recall, analyse, interpret, apply and question scientific information or ideas.	**Key processes: Interpreting and evaluating** Students should be able to: • form convincing arguments to justify findings and general statements • consider the assumptions made and the appropriateness and accuracy of results and conclusions • appreciate the strength of empirical evidence and distinguish between evidence and proof • look at data to find patterns and exceptions • relate their findings to the original question or conjecture, and indicate reliability • make sense of someone else's findings and judge their value in the light of the evidence they present • critically examine strategies adopted.

Technology and application

There are some differences across the curricula analysed, in terms of the relationship of key scientific concepts to application and technology. Some curricula place great emphasis on technology. For example: its importance is emphasised as part of the curriculum background information; there may be explicit references to application within subject domains; or its content may be presented as a separate domain. For example: Alberta identifies technology and society as one of the foundations of its science programme, alongside knowledge in key domains, skills and attitudes; Massachusetts has a specific domain on *engineering and technology*; Hong Kong has elements in General Studies relating to technology and application; and Singapore emphasises the importance of application in the technological world within its aims and vision. This relationship is not particularly emphasised in England (1999 and 2007), although there are some elements within the sub-domains and introductory text. However, it should be noted that the analysis did not cover the subject of Design and Technology (or equivalent) across the jurisdictions analysed.

5.7 Domains

As set out in Section 5.4, the main domains for science are *biology*, *chemistry* and *physics*. The tables at Appendix C (Tables C2-C4) provide an overview of the content for England and the five comparator jurisdictions analysed in relation to *biology, chemistry, physics and Earth science*. It should be noted that the content is not intended to be a fully comprehensive analysis of all science content but it does cover the majority of content.

The mapping suggests that despite some variation in structure and organisation, the analysis has shown a commonality of content in the science disciplines that can be organised into domains and sub-domains.

In the following analysis, the focus is on a selection of domains and sub-domains rather than a comprehensive analysis of all the content, together with a number of examples to illustrate key differences between the England National Curriculum and the statutory curricula of high-performing jurisdictions, focusing in particular on where the content of high-performing jurisdictions appears more challenging than in England.

These examples are intended to illustrate where the new National Curriculum for science can be strengthened so that the content, standards and expectations are on a par with highest-performing jurisdictions. The analysis includes:

- *Biology;*
- *Chemistry;*
- *Physics; and*
- *Earth science*.

The tables at Appendix C provide a summary of the curriculum content analysed, rather than present the content verbatim, in order to facilitate direct comparisons and for the sake of accessibility and brevity.

Biology

Across the curricula analysed, coverage of the key sub-domains and concepts for *biology* seems comparable. All cover *structure and function*; *interactions and interdependency*; *energy*; and *evolution*. All include *animals*, including *humans*, and *plants*. Set out below is a summary of the content across the key sub-domains as set out in Appendix C (Table C2).

- ***Classification:*** This is covered across all curricula and phases, starting from simple classification based on observable features in Years 1 and 2 in England, Alberta and Massachusetts but Years 4-6 in Hong Kong and Singapore. Classification is also covered in secondary across all the jurisdictions using, for example, Five Kingdom classification. This is usually introduced during Years 7-9.

- ***Structure and function:*** This is the most extensive sub-domain in *biology*. Therefore, to assist the analysis, it has been broken down in Table C2 into *animals* including *humans*, *plants* and *cells*. This sub-domain starts with simple external body parts or parts of plants in early primary. *Internal organs* and *systems* are introduced in late primary in England and Singapore; but elsewhere in secondary. *Cells* are usually introduced in early secondary, with the exception of Singapore where they are introduced in late primary.

- ***Interactions and interdependencies:*** This is largely covered across all curricula although there are some differences in terms of the amount of content, i.e. there seems to be more content in Alberta where there are sub-domains covering different types of ecosystems e.g. fresh and salt water, forests etc.

- ***Energy:*** This is covered across all curricula reviewed for both plants and animals, including *humans*. The key common elements are *photosynthesis, digestion* and *food chains*. There seems to be less coverage of *plants* in the Hong Kong curriculum.

- ***Evolution:*** This is covered across all curricula and includes key concepts such as *variation* and *inheritance*. Coverage is very detailed in Alberta and Massachusetts, for example, where the latter includes the work of Mendel and Darwin.

One example where curricula in high-performing jurisdictions seem to be more challenging than in England is in relation to *cells*. *Cells* are introduced in upper primary in Singapore (equivalent to Year 6); whereas they are introduced in lower secondary (Years 7-9) in England. Their content is broadly similar in that they both specify cell structure and function. However, the Singapore curriculum is more challenging in three ways: by learning the different parts and their functions in both plant and animal cells at primary; by explicitly setting out the need to examine the different parts of the cell at lower secondary; and by being more explicit about the life processes to be studied at the cellular level in both upper primary and lower secondary (See Table 5.5).

Table 5.5: Example of coverage of cells in primary: England (1999) and Singapore (2001)

England 1999	Singapore 2001
Years 1-6 Cells not specified in Years 1-6.	**Year 6** Show an understanding that a cell is a basic unit of life. Identify the typical parts of a plant cell and relate the parts to the functions: • cell wall • cell membrane • cytoplasm • nucleus • chloroplasts Identify the different parts of a typical animal cell and relate the parts to the functions: • cell membrane • cytoplasm • nucleus Show an understanding that a cell divides to produce new cells and that this division is necessary for an organism to grow
Years 7-9 (1999) Pupils should be taught: • that animal and plant cells can form tissues, and tissues can form organs	**Year 8 (2001)** Examine plant cells under microscope and identify the different parts of a cell: • cell wall

England 1999	Singapore 2001
• the functions of chloroplasts and cell walls in plant cells and the functions of the cell membrane, cytoplasm and nucleus in both plant and animal cells • to relate cells and cell functions to life processes in a variety of organisms. **Years 10-11 (2007)** The ways in which organisms function are related to the genes in their cells.	• cell membrane • cytoplasm • nucleus • vacuole • chloroplast Examine animal cell under microscope and identify the different parts of the animal cell: • cell membrane • cytoplasm • nucleus Compare a typical plant cell and typical animal cell show an understanding of the functions of the different parts of a cell, including the nucleus which contains genetic material that determines heredity. Recognise that multi-cellular organisms (both plants and animals), cells of similar structures are organised into tissues; several tissues may make up an organ; organs are organised into systems Explain the significance of the division of labour, even at the cellular level

Chemistry

All jurisdictions cover the sub-domains of *nature of matter and energy*; *physical change*; *chemical change*; and *properties of materials*.

- ***Physical change:*** The different *states of matter* are commonly introduced at primary level. They are explained in terms of *particles* and *energy transfer* at lower secondary level. *Mixtures* are generally introduced at lower secondary level, and techniques for separating out mixtures appear mostly at lower secondary level.

- ***Chemical change:*** Only England introduces a *distinction between physical and chemical change* at primary level. The domain is mainly introduced at lower secondary level. Understanding *patterns of chemical change* in terms of the model of the atom, chemical bonding and the patterns of the Periodic Table appears at upper secondary. Curricula commonly specify that reactions should include combustion, thermal decomposition, oxidisation and neutralisation.

- ***Properties of materials:*** All jurisdictions introduce *the relationship between properties of materials and their uses* at early primary. At lower secondary, pupils are introduced to the *properties of particular elements and groups of elements*, and the *production of useful new substances by chemical reaction*. At upper secondary, curricula mostly demand deeper and more quantitative understanding of the *various types of reaction* (for example, control of rate of reaction by use of catalysts, and calculations of chemical yield). Only England, Singapore and Hong Kong include detailed coverage of products of crude oil.

One example where the curriculum of high-performing jurisdictions seems more challenging than in England is in relation to *industrial processes*. England and Hong Kong both introduce key chemistry concepts in lower secondary, namely: *atoms and elements*: *compounds as consisting of atoms/elements chemically combined in specific proportions*; *mixtures as consisting of substances that are not chemically combined*; and *separation of mixtures by fractional distillation*.

Table 5.6: Example of crude oil and plastics: England (1999, 2007) and Hong Kong (1998)

England (1999, 2007)	Hong Kong 1998
Year 7-9 (1999) Pupils should be taught: • How materials can be characterised by melting point, boiling point and density. • How elements combine through chemical reactions to form compounds with a definite composition. • That mixtures are composed of constituents that are not combined. • How to separate mixtures into their constituents using distillation, chromatography and other appropriate methods. • That virtually all materials, including those in living systems, are made through chemical reactions, and to recognise the importance of chemical change in everyday situations. **Year 10-11 (2007)** • elements consist of atoms that combine together in chemical reactions to form compounds	**Year 7-9** • Crude oil is a mixture of hydrocarbons. • Hydrocarbons are compounds of hydrogen and carbon. • Different hydrocarbon molecules are of different size; they consist of different number of carbon and hydrogen atoms. • Molecule as group of atoms that forms the smallest stable unit of some elements or compounds. • Separation of crude oil into different fractions by fractional distillation. • Different fractions consist of hydro-carbons of different boiling points. • Making plastics: small hydrocarbon molecules can be joined together to produce macro-molecules e.g. ethane (obtained by the breaking down of naphtha) to polythene.
Year 10-11 (1999) Pupils should be taught: • That new substances are formed when atoms combine • How the mixture of substances in crude oil, most of which are hydrocarbons, can be separated by fractional distillation • How addition polymers can be formed from the products of crude oil by cracking and polymerisation **Year 10-11 (2007)** • new materials are made from natural resources by chemical reactions	**Year 10-11** • Petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation. • Relation of the gradation in properties (e.g. colour, viscosity, volatility and burning characteristics) with the number of carbon atoms in the molecules of the various fractions. • Monomers, polymers and repeating units. • Addition polymerisation

However, in Hong Kong pupils are also required to be taught about the *manufacture of plastics* (see Table 5.6). Thus, crude oil is identified as a mixture of hydrocarbons, and the separation of crude oil into its fractions is followed by coverage of the manufacture of plastics by joining small hydrocarbons to form macro-molecules. Non-statutory guidance is also provided on practical experiments involving distilling a small amount of crude oil and investigating the properties of its products and making epoxy resin. In England, the manufacture of plastic from crude oil is not covered until upper secondary (at upper secondary level, both England and Hong Kong cover manufacture of plastic from crude oil at similar depth, introducing the chemical concept of polymerisation).

Physics

Across the curricula reviewed, there were a number of different sub-domains which covered *forces and motion*, *light, sound and waves*, *electricity and magnetism*, *energy and matter*, and *the earth and universe*:

- ***Matter and energy (also part of chemistry):*** Covered in all curricula with typical sub-domains of *types of energy, conservation of energy* and *properties of matter*. A basic understanding of the *conservation of matter* is introduced at primary in Singapore; however, this domain is mainly introduced in all jurisdictions at lower secondary as *particulate nature of matter* (atoms, molecules, elements and compounds). Demonstration of *conservation of matter* through quantitative interpretation of equations is introduced at upper secondary, as is the concept of *conservation of energy*.

- ***Forces and motion:*** This is covered in all the curricula analysed and includes sub-domains such as *concepts of forces, laws of motion, position* and *movement*;

- ***Light, sound and waves:*** Covered in all curricula although in less detail in England 2007. Other curricula include *reflection and refraction*, *spectrum*, *vibration*, *pitch and loudness*, properties *and characteristics of waves*, *waves in relation to light and sound* and *the electromagnetic spectrum*;

- ***Electricity and magnetism:*** Covered in most curricula, progressing from simple circuits through to sub-domains such as *current, resistance, voltage, magnets, conductors* and *insulation and electromagnetism*;

- ***The earth and universe:*** Covered in all curricula with typical sub-domains of: *the sun, earth and moon relationships*, *the solar system* and *origins of the universe*.

One example of where the curricula of high-performing jurisdictions seem more challenging is in relation to forces and machines. Table 5.7 shows the different expectations to the introduction of *forces and motion* in England and Singapore. In England, the types of forces covered within *forces and motion* at primary level only include simple linear *forces and motion*. Those involving motion around a pivot are not introduced until lower secondary school (Year 7-9). In Singapore, primary pupils in Year 6 equivalent are required to apply their understanding of forces by manipulating simple machines, including ones that involve rotation around a pivot (wheel and axle, gears). This difference in level of challenge between England and Singapore was also noted by Ruddock and Sainsbury (2008)[126], who concluded that physical sciences in

[126] Ruddock, G. and Sainsbury, M. (2008). *Comparison of the core primary curriculum in England to*

the Singapore primary curriculum are broader and slightly harder than in England.

Table 5.7: Example of forces and machines: England (1999) and Singapore (2001)

England	Singapore
Years 3-6 (1999) Pupils should be taught: *Types of force* • that when objects (for example, a spring, a table) are pushed or pulled, an opposing pull or push can be felt • how to measure forces and identify the direction in which they act. **Years 7-9 (1999)** Pupils should be taught: *Forces and rotation* • that forces can cause objects to turn about a pivot • the principle of moments and its application to situations involving one pivot	**Year 6 (2001)** • identify a force as a push or a pull. • list some simple machines. [Curriculum remarks: The simple machines are lever, pulley, wheel and axle, inclined plane, gears.] • manipulate these simple machines to determine their characteristics and uses.

Earth science

As set out in Section 2.6, *earth and space* was identified among other domains as an particular area for improvement in the analysis of PISA results for England. Table C8 (Appendix C) provides a map of the content of the curricula reviewed in terms of coverage of material on earth science[127].

Some curricula cover this in more detail than others. For example, in Massachusetts and Alberta e*arth and space science* is a separate discipline at both primary and secondary; and is therefore covered in detail. However, there seems to be less coverage in other curricula, such as Singapore and Hong Kong.

For England (1999), *earth science* material is covered across the three science disciplines and is therefore not presented as a single discipline. However, in England (2007), *earth and space* content is set out separately from the content of *biology*, *chemistry* and *physics* as *the environment, Earth and the universe* (although there are, of course, overlaps with the other disciplines).

those of other high performing countries. DCSF Research Report DCSF-RW048.

[127] ‘Earth science’ includes content related to the lithosphere, atmosphere, hydrosphere, biosphere, oceans, the physical aspects of the earth and the relationship of earth in the universe.

Appendix 1: Background on PISA, PIRLS and TIMSS studies

This appendix provides background information on PISA, PIRLS and TIMSS, together with a more detailed breakdown of the different domains of reading, mathematics and science that were assessed in the most recent waves, namely PISA 2009, PIRLS 2006 and TIMSS 2007.

PISA

PISA is a series of surveys and tests that are administered by the Organisation for Economic Co-operation and Development (OECD) triennially to 15-year-old pupils in OECD member countries and also partner countries and economies. The most recent round of PISA was conducted in 2009, with earlier rounds occurring in 2000, 2003 and 2006. The PISA tests focus on reading, mathematics and science, and aim to assess the extent to which pupils nearing the end of compulsory education have acquired the knowledge and skills that have been selected by PISA as important for full participation in society[128]. Each assessment wave of PISA focuses on a different subject selected from literacy, mathematics and science. Two-thirds of testing time is devoted to the focus subject in each wave, to provide a detailed measurement of performance against several sub-areas within that subject. The assessment of the remaining subjects (mathematics and science in PISA 2009) provides a less detailed summary of performance.

For the 2009 wave, the tests took the format of paper-and-pencil tests lasting two hours for each pupil, with an additional elective test in which 40 minutes were allocated for the assessment of the reading and understanding of electronic texts, taken in some education systems but not others. Test items consisted of a mixture of multiple choice items and questions that required pupils to formulate their own responses (constructed response items). Test items were organised in groups based on a passage which describes a real-life situation. In total, 390 minutes of test-items were covered by PISA in 2009, with different groups of pupils attempting different combinations of items. PISA 2009 also included a 30 minute pupil questionnaire which asked participants about their background, their learning habits, attitudes to reading, along with their involvement and motivation. There was also a questionnaire administered to school principals to gather demographic information about their school, in addition to an assessment of the learning quality of the school[129].

PIRLS

PIRLS is a system of regular assessment of pupil's reading literacy in their fourth year of formal schooling (approximately aged 10) that is undertaken in multiple jurisdictions and is administered by the International Association for the Evaluation of Educational Achievement (IEA). The PIRLS programme was established in 2001 and is conducted every five years, with the second wave undertaken in 2006. Its principal aim is to measure the progress made by education systems in pupils' reading ability,

[128] OECD (2010c). *PISA 2009 Results: What Makes a School Successful? – Resources, Policies and Practices (Volume IV)*. Paris: OECD Publishing
[129] OECD (2009). *PISA 2009 Assessment Framework: Key competencies in reading, mathematics and science.* Paris: OECD Publishing

along with trends in any associated home and school contexts that might affect children's progress in learning to read[130].

PIRLS 2006 focused on assessing a range of reading comprehension processes under two major reading purposes, namely *literary* and *informational*. PIRLS 2006 used a series of booklets as a means of assessing reading literacy, with booklets containing five literary passages and five informational passages. Each passage was accompanied by 12 questions, about half of which were multiple choice, with the other half consisting of constructed-response format questions. Altogether the assessment consisted of 126 test items. The PIRLS 2006 assessment also included questionnaires administered to pupils, teachers and school principals in order to collect information on classrooms and schools, along with questionnaires to parents and caregivers to collect information on the home and school environments for learning to read[131].

TIMSS

TIMSS is undertaken every four years and assesses achievements in mathematics and science for pupils at the end of four years of formal schooling (aged approximately 10) and at the end of eight years of formal schooling (aged approximately 14). TIMSS is administered by the International Association for the Evaluation of Educational Achievement (IEA), and was first undertaken in 1995[132], with following waves occurring in 1999, 2003 and 2007. The 2007 wave of TIMSS included questionnaires completed by participating jurisdictions on their education system, and teachers were asked to complete questionnaires identifying which TIMSS topics were taught to pupils as part of the curriculum. Pupils completed questionnaires on their home and classroom experiences, and school principals and teachers provided information on school resources, the learning climate and instructional practices[133].

All tests within TIMSS 2007 (both mathematics and science, at age 10 and 14) were organized around two dimensions. These were a content dimension, which specified the subject domains to be assessed, and a cognitive dimension which specified the thinking processes to be assessed. The mathematics assessment for pupils aged 10 included 179 test items; the age 14 assessment had 215. The science assessment for pupils aged 10 included 174 test items; the age 14 assessment had 214. For both the science and mathematics assessments at both ages, around half the items were

[130] Mullis, I.V.S. Martin, M.O. Kennedy, A.M. Trong, K.L. and Sainsbury, M. (2009). *PIRLS 2011 Assessment Framework*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

[131] Mullis, I.V.S. Martin, M.O. Kennedy, A.M. and Foy, P. (2007). *PIRLS 2006 International Report: IEA's Progress in International Reading Literacy Study in Primary Schools in 40 Countries*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

[132] Although TIMSS was first administered in 1995, it built on the earlier First International Mathematics Study (FIMS) and Second International Mathematics Study (SIMS) assessments. FIMS was undertaken between 1961 and 1965, and SIMS between 1980 and 1982. These earlier assessments only focused on maths, and did not include science. Mullis, I.V.S. and Martin, M.O. (2006). *TIMSS in Perspective: Lessons Learned from IEA's Four Decades of International Mathematics Assessments.* Last retrieved 15th November 2011 from http://www.brookings.edu/gs/brown/irc2006conference/MullisMartin_paper.pdf

[133] Mullis, I.V.S. Martin, M.O. and Foy, P. (with Olson, J.F. Preuschoff, C. Erberber, E. Arora, A. and Galia, J.) (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

multiple-choice responses, the other half were constructed responses[134] [135].

Domains measured in PISA, PIRLS and TIMSS

Outlined below are details of the reading, mathematics and science sub-domains assessed in PISA 2009, PIRLS 2006 and TIMSS 2007.

Reading processes in PIRLS 2006

[Source: PIRLS 2006 Assessment Framework[136]]

Interpreting ideas and information typically involves:
- discerning the overall message or theme of a text;
- considering an alternative to actions of characters;
- evaluating the likelihood that the events described could actually happen; and
- describing how the author devised a surprise ending.

Making straightforward inferences typically involves:
- looking for specific ideas;
- searching for definitions of words or phrases;
- concluding what the main point is of a series of arguments; and
- determining the referent of a pronoun.

Reading processes in PISA 2009

[Source: PISA 2009 Assessment Framework[137]]

Accessing and retrieving information typically involves:
- locating the details required by an employer from a job advertisement;
- finding a telephone number with several prefix codes; and
- finding a particular fact to support or disprove a claim someone has made.

Integrating and interpreting typically involves:
- recognising a relationship that is not explicit;
- inferring (from evidence and reasoning) the connotation of a phrase or a sentence;
- processing the text to form a summary of the main ideas; and
- connecting various pieces of information to make meaning.

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[134] Mullis, I.V.S. Martin, M.O. and Foy, P. (with Olson, J.F. Preuschoff, C. Erberber, E. Arora, A. and Galia, J.) (2008). *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[135] Martin, M.O. Mullis, I.V.S. and Foy, P. (with Olson, J.F. Erberber, E. Preuschoff, C. and Galia, C.) (2008). *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.
[136] Mullis, I. Kennedy, A. Martin, M. and Sainsbury, M. (2006). *PIRLS 2006 Assessment Framework and Specifications*, *2nd Edition*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Boston College.
[137] OECD (2009). *PISA 2009 Assessment Framework – Key competencies in reading, mathematics and science.* Paris: OECD Publishing.

Reflecting and evaluating typically involves:

- connecting information in a text to knowledge from outside sources; and
- assessing the claims made in the text against their own knowledge of the world articulating and defending a point of view.

Mathematics domains at age 10 in TIMSS 2007

[Source: TIMSS 2007 Assessment Framework[138]]

Number typically involves such tasks as:

- recognising multiples and factors of numbers;
- adding and subtracting fractions and decimals;
- Finding the missing number in a number sentence, *e.g.* 13 + ? = 21; and
- describing relationships between adjacent numbers in a sequence.

Geometric shapes and measures typically involve such tasks as:

- comparing angles by size and drawing angles;
- calculating areas and perimeters of squares and rectangles; and
- drawing reflections and rotations of figures.

Data display typically involves such tasks as:

- comparing information from different data sets; and
- displaying data in bar charts and pictographs.

Knowing typically involves:

- recalling definitions and properties;
- recognising mathematical objects;
- computational procedures;
- retrieving information;
- measuring; and
- classifying objects according to common properties.

Applying typically involves:

- selecting the right procedure to solve a problem;
- displaying mathematical information;
- generating a model (*e.g.* an equation) for solving a routine problem;
- following mathematical instructions; and
- solving routine problems (of a type that will be familiar).

Reasoning typically involves:

- making valid inferences from given information;
- restating results in a more widely applicable form;
- making linkages between different mathematical ideas;
- justifying a statement using mathematical reasoning; and
- solving non-routine problems.

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[138] Mullis, I. Martin, M. Ruddock, G. O'Sullivan, C. Arora, A. and Erberber, E. (2007). *TIMSS 2007 Assessment Frameworks.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

Mathematics domains at age 14 in TIMSS 2007

[Source: TIMSS 2007 Assessment Framework[139]]

Number typically involves such tasks as:

- evaluating powers of numbers and square roots of perfect squares to 144;
- converting between fractions and decimals; and
- dividing a quantity in a given ratio.

Algebra typically involves such tasks as:

- showing pattern relationships in a sequence using algebraic expressions;
- comparing algebraic expressions to show equivalence; and
- solving simple linear and two-variable equations.

Geometry typically involves such tasks as:

- using Pythagoras's Theorem to solve problems;
- finding a way to measure irregular or compound areas; and
- demonstrating translation, reflection and rotation.

Data and chance typically involves such tasks as:

- matching different representations of the same data;
- recognising approaches to displaying data that could lead to confusion; and
- determining the chances of possible outcomes.

Knowing typically involves:

- recalling definitions and properties;
- recognising mathematical objects;
- computational procedures;
- retrieving information;
- measuring; and
- classifying objects according to common properties.

Applying typically involves:

- selecting the right procedure to solve a problem;
- displaying mathematical information;
- generating a model (*e.g.* an equation) for solving a routine problem;
- following mathematical instructions; and
- solving routine problems (of a type that will be familiar).

Reasoning typically involves:

- making valid inferences from given information;
- restating results in a more widely applicable form;
- making linkages between different mathematical ideas;
- justifying a statement using mathematical reasoning; and

[139] Mullis, I. Martin, M. Ruddock, G. O'Sullivan, C. Arora, A. and Erberber, E. (2007). *TIMSS 2007 Assessment Frameworks.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

- solving non-routine problems.

Science domains at age 10 in TIMSS 2007

[Source: TIMSS 2007 Assessment Framework[140]]

Life science typically involves such tasks as:
- relating body structures to their function;
- comparing the life cycles of familiar organisms;
- associating physical features of organisms with their environment;
- explaining relationships in a community based on food chains; and
- describing ways of maintaining good human health.

Physical science typically involves such tasks as:
- describing mixtures on the basis of physical appearance;
- describing difference between liquids, solids and gases;
- identifying common materials that conduct heat;
- recognising that sound is produced by vibrations;
- identifying a complete electrical circuit; and
- identifying familiar forces that cause objects to move.

Earth science typically involves such tasks as:
- identifying examples of the uses of air;
- relating the formations of clouds to change of state of water; and
- relating daily patterns observed on Earth to its rotation.

Knowing typically involves:
- recalling scientific facts and concepts;
- defining scientific terms;
- describing organisms, materials or science processes;
- supporting statements of fact with examples; and
- knowing how to use scientific tools and procedures.

Applying typically involves:
- comparing and contrasting organisms, materials or processes;
- using a diagram or model to demonstrate understanding;
- relating knowledge of a concept or property to observed behaviour;
- interpreting information in the light of a scientific concept;
- using a relationship, equation or formula to find a solution; and
- explaining an observation or phenomenon using scientific knowledge.

Reasoning typically involves:
- analysing a problem to determine the right steps to solve it;
- synthesising a number of different concepts;
- forming hypotheses to explain observations;

[140] Mullis, I. Martin, M. Ruddock, G. O'Sullivan, C. Arora, A. and Erberber, E. (2007). *TIMSS 2007 Assessment Frameworks.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

- designing an investigation to answer a question;
- drawing conclusions from patterns in data;
- drawing conclusions that go beyond observed conditions; and
- evaluating the results of investigations.

Science domains at age 14 in TIMSS 2007 Science

[Source: TIMSS 2007 Assessment Framework[141]]

Biology typically involves such tasks as:
- locating the major organs of the human body;
- identifying cell structures and the functions of some organs;
- relating the inheritance of traits to the passing on of genetic material;
- relating the survival of species to reproductive success;
- describing the role of organisms in cycling materials; and
- describing causes of common infectious diseases.

Chemistry typically involves such tasks as:
- differentiating between pure substances and mixtures;
- relating the behaviour of water to its physical properties; and
- recognising that mass is conserved during chemical change.

Physics typically involves such tasks as:
- recognising that mass is conserved during physical changes;
- identifying different forms of energy;
- interpreting ray diagrams to identify the path of light;
- describing some basic properties of sound;
- identifying practical uses of electromagnets; and
- predicting changes of motion of an object due to forces acting on it.

Earth science typically involves such tasks as:
- interpreting topographical maps;
- describing the steps of the Earth's water cycle;
- providing examples of renewable and non-renewable resources; and
- contrasting the physical features of Earth with other planets.

Knowing typically involves:
- recalling scientific facts and concepts;
- defining scientific terms;
- describing organisms, materials or science processes;
- supporting statements of fact with examples; and
- knowing how to use scientific tools and procedures.

Applying typically involves:
- comparing and contrasting organisms, materials or processes;

[141] Mullis, I. Martin, M. Ruddock, G. O'Sullivan, C. Arora, A. and Erberber, E. (2007). *TIMSS 2007 Assessment Frameworks.* Chestnut Hill, MA: TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College.

- using a diagram or model to demonstrate understanding;
- relating knowledge of a concept or property to observed behaviour;
- interpreting information in the light of a scientific concept;
- using a relationship, equation or formula to find a solution; and
- explaining an observation or phenomenon using scientific knowledge.

Reasoning typically involves:
- analysing a problem to determine the right steps to solve it;
- synthesising a number of different concepts;
- forming hypotheses to explain observations;
- designing an investigation to answer a question;
- drawing conclusions from patterns in data;
- drawing conclusions that go beyond observed conditions; and
- evaluating the results of investigations.

Science at age 15 in PISA 2006

[Source: PISA 2006 Assessment Framework[142]]

Identifying scientific issues typically involves:
- Recognising issues that it is possible to investigate scientifically;
- Identifying keywords to search for scientific information; and
- Recognising the key features of a scientific investigation.

Explaining phenomena scientifically typically involves:
- Applying knowledge of science in a given situation;
- Describing or interpreting phenomena scientifically and predicting changes; and
- Identifying appropriate descriptions, explanations, and predictions.

Using scientific evidence typically involves:
- Interpreting scientific evidence; making and communicating conclusions;
- Identifying the assumptions, evidence and reasoning behind conclusions; and
- Reflecting on the implications of scientific or technological developments.

Knowledge about science typically involves such tasks as:
- Identifying fruitful questions for scientific enquiry;
- Identifying the assumptions made by a given scientific study; and
- Identifying possible weaknesses in an experimental method.

Earth and space systems typically involves:
- Structures of the Earth systems (*e.g.* lithosphere, atmosphere);
- Energy in the Earth systems (*e.g.* sources, global climate);
- Change in Earth systems (*e.g.* plate tectonics, geochemical cycles);
- Earth's history (*e.g.* fossils, origin and evolution); and
- Earth in space (*e.g.* gravity, solar systems).

[142] OECD (2009). *PISA 2009 Assessment Framework – Key competencies in reading, mathematics and science.* Paris: OECD Publishing.

Living systems typically involves:

- Cells (*e.g.* structures and function, DNA, plant and animal);
- Humans (*e.g.* health, nutrition, disease, reproduction);
- Populations (*e.g.* species, evolution, biodiversity, genetic variation);
- Ecosystems (*e.g.* food chains, matter and energy flow); and
- Biosphere (*e.g.* ecosystem services, sustainability.

Physical systems typically involves:

- Structure of matter (*e.g.* particle model, bonds);
- Properties of matter (*e.g.* changes of state, thermal conductivity);
- Chemical changes of matter (*e.g.* reactions, energy transfer, acids/bases);
- Motions and forces (*e.g.* velocity, friction);
- Energy and its transformation (*e.g.* conservation, chemical reactions); and
- Interactions of energy and matter (*e.g.* light and radio waves).

Appendix 2: Curriculum document references

English

England 1999 English Key Stages 1 to 4
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/English%201999%20programme%20of%20study_tcm8-12054.pdf

England 2007 English Key Stage 3
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3332-pEnglish3_tcm8-399.pdf

England 2007 English Key Stage 4
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3333-pEnglish4_tcm8-415.pdf

Alberta 2000 English Language Arts: Grades K-9
http://education.alberta.ca/media/450519/elak-9.pdf

Alberta 2003 English Language Arts: Grades 10-12
http://education.alberta.ca/media/645805/srhelapofs.pdf

Massachusetts 2001 'English Language Arts': Grades Pre-K to 12
http://www.doe.mass.edu/frameworks/ela/0601.doc

New Zealand 1994 'English' Levels 1 to 8
http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/Schools/EnglishInTheNewZealandCurriculum.pdf

New South Wales 2007 (first published 1998) 'English' K to 6
http://k6.boardofstudies.nsw.edu.au/files/english/k6_english_syl.pdf

New South Wales 2003 'English' Years 7 to 10
http://www.boardofstudies.nsw.edu.au/syllabus_sc/pdf_doc/english_710_syllabus.pdf

Singapore 2001 'English Language for Primary and Secondary Schools
http://www.moe.gov.sg/education/syllabuses/languages-and-literature/files/english-primary-secondary.pdf

Mathematics

England 1999
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/Mathematics%201999%20programme%20of%20study_tcm8-12059.pdf

England 2007 KS3
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3338-p_Maths_3_tcm8-403.pdf

England 2007 KS4
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3339-p_Maths_4_tcm8-404.pdf

Finland (Mathematics – Chapter 7.6)
http://www.oph.fi/download/47672_core_curricula_basic_education_3.pdf

Flemish Belgium (2010)
Mainstream primary education
http://www.ond.vlaanderen.be/dvo/english/corecurriculum/primary/indexprimary.htm
First stage of mainstream secondary education A-stream
http://www.ond.vlaanderen.be/dvo/english/corecurriculum/secondary/1grade/astream/indexstreama.htm
Second stage of mainstream secondary education
http://www.ond.vlaanderen.be/dvo/english/corecurriculum/secondary/2grade/index.htm
Third stage of mainstream secondary education
http://www.ond.vlaanderen.be/dvo/english/corecurriculum/secondary/3grade/index.htm

Hong Kong Primary 2000
http://www.edb.gov.hk/index.aspx?nodeID=4907&langno=1

Hong Kong Secondary 1999
http://www.edb.gov.hk/index.aspx?nodeID=4905&langno=1

Massachusetts 2000
http://www.doe.mass.edu/frameworks/math/2000/final.pdf

Massachusetts Addendum 2004
http://www.doe.mass.edu/frameworks/math/052504_sup.pdf

Singapore curriculum Primary 2001
http://www3.moe.edu.sg/cpdd/doc/Maths_Pri.pdf

Singapore Primary 2007
http://www.moe.gov.sg/education/syllabuses/sciences/files/maths-primary-2007.pdf

Singapore Secondary 2007
http://www.moe.gov.sg/education/syllabuses/sciences/files/maths-secondary.pdf

Science

England 1999
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/Science%201999%20programme%20of%20study_tcm8-12062.pdf

England 2007 Key Stage 3
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3344-p_Science_KS3_tcm8-413.pdf

England 2007 Key Stage 4
http://webarchive.nationalarchives.gov.uk/20101221004558/http://curriculum.qcda.gov.uk/uploads/QCA-07-3345-p_Science_KS4_tcm8-1799.pdf

Alberta 1996 (G1-G6)
http://education.alberta.ca/media/654825/elemsci.pdf

Alberta 2003 (G7-G9)
http://education.alberta.ca/media/654829/sci7to9.pdf

Alberta 2007 (G10-12 Science)
http://education.alberta.ca/media/654837/sci2030_07.pdf

Alberta 2007 (G10-12 biology)
http://education.alberta.ca/media/654841/bio203007.pdf

Alberta 2007 (G10-12 chemistry)
http://education.alberta.ca/media/654849/chem2030_07.pdf

Alberta 2007 (G10-12 physics)
http://education.alberta.ca/media/654853/phy2030_07.pdf

Hong Kong 2002 (KS1 & KS2)
https://cd.edb.gov.hk/kla_guide/GS_HTML/english/frame.html
[Note Science is taught as part of general studies in primary]

Hong Kong 1998 (Sec1-3)
http://cd1.edb.hkedcity.net/cd/science/is/sci_syllabus_S1to3_e.pdf

Hong Kong 2007 (KS4 Combined Science)
http://www.edb.gov.hk/FileManager/EN/Content_2855/com_sci_final_e_20091005.pdf

Hong Kong 2007 (KS4 Biology)
http://www.edb.gov.hk/FileManager/EN/Content_2855/bio_final_e_20091005.pdf

Hong Kong 2007 (KS4 Chemistry)
http://www.edb.gov.hk/FileManager/EN/Content_2855/chem_final_e_20091005.pdf

Hong Kong 2007 (KS4 Physics)
http://www.edb.gov.hk/FileManager/EN/Content_2855/phy_final_e_20091005.pdf

Massachusetts 2006 (K-G9)
http://www.doe.mass.edu/frameworks/scitech/1006.pdf

Singapore 2001 (P1-P6)
http://www3.moe.edu.sg/cpdd/doc/Science_Pri.pdf

Singapore 2001 (Lower Secondary 1&2)
http://www3.moe.edu.sg/cpdd/doc/Science_LowSec_All.pdf

Victoria – 2008- Scientific enquiry (Level 1-Level 6)
http://vels.vcaa.vic.edu.au/downloads/vels_standards/velsrevisedscience.pdf

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