Nuffield Foundation

Response to the National Curriculum Review

April 2011

Introduction

Lord Nuffield established the Nuffield Foundation to contribute to improvements in society, including the expansion of education and the alleviation of disadvantage. Today, we work to improve social well-being by funding research and innovation in education and social policy.

We see mathematical, statistical and scientific literacy as critical for achieving the above goals. The Foundation is committed to improving mathematics and science education for *all*. This includes fostering increased participation and achievement by supporting pathways appropriate for learners' current and future needs.

Our response below aims to address some of the questions in the consultation, but also comments more broadly at times.

Summary of recommendations from the Nuffield Foundation

1) *Mathematical content specified in the National Curriculum should contain a balance of concepts and processes.*

2) *Science content specified in the National Curriculum should contain a balance of scientific concepts and processes. It should also specify practical work in terms of the essential understanding and competencies which need to be demonstrated by pupils.*

3) *Design and Technology should be given due prominence in the National Curriculum to ensure that pupils experience this important aspect of their STEM education.*

4) *The importance of modern languages for the UK should be reflected in the current review of the curriculum.*

5) *The review should draw on the research on Twenty First Century Science (a GCSE curriculum project developed by the Nuffield Foundation and the University of York) as a model for GCSE pathways and content. In particular, the curriculum review should consider how the curriculum for science can fulfil the diverse needs of the full range of pupils.*

6) *The curriculum review should ensure the continuation and development of the applied science route and its progression pathways.*

7) *The National Curriculum should define a minimal core, but leave plenty of potential for a range of additional content.*

8) *A range of approaches for the different needs of pupils should be provided in the 14-19 science and mathematics pathways.*

9) *Summative and formative assessment should be considered as the content of the curriculum is reviewed. Assessment should be designed to drive teaching and learning through inquiry, practical work and discussion, which are essential to science and mathematics education.*

10) *The UK curriculum needs to align itself with future developments rather than looking back. The curriculum review should consider carefully the directions that are emerging from the plans for future PISA tests to ensure that UK does not fall behind in international comparisons as a result of moving the mathematics and science curricula in a different direction.*

11) *The curriculum review should consult widely with the educational research communities to ensure a curriculum based on a sound, evidence based educational framework.*

12) *We recommend the review takes the opportunity to coordinate the curriculum and highlight cross-curricular links to allow related subjects to support and reinforce each other.*

13) *The Review should consider carefully the transition to the new National Curriculum. Existing organisations such as the National Network of Science Learning Centres and HEIs which engage with schools should continue to be supported to provide a continuing programme of teacher professional development.*

Responses to the consultation questions

SECTION D: 10 a) Mathematics

What knowledge do you regard as essential to include in the Programme of Study for **mathematics**?

We do not consider it appropriate for the Foundation to provide a list of topics. We would however make the obvious but fundamental point that Mathematics is not a collection of facts. Processes and applications are as important as the key concepts, and this should be reflected in the National Curriculum. We recommend study of the *Adding it up*[1] report of the US National Research Council, which has identified five "strands of mathematical proficiency":

> *…… conceptual understanding—comprehension of mathematical concepts, operations, and relations; procedural fluency—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately; strategic competence—ability to formulate, represent, and solve mathematical problems; adaptive reasoning—capacity for logical thought, reflection, explanation, and justification; productive disposition—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy. These strands are not independent and they represent different aspects of a complex whole.*

1) *Mathematical content specified in the National Curriculum should contain a balance of concepts and processes.*

11 a) Science

What knowledge do you regard as essential to include in the Programme(s) of Study for **science**?

As for mathematics, so for science. Science is not just a collection of facts. The processes and applications of science are as important as the key concepts. This fundamental principle is commonplace in statements from senior scientific bodies across the world.

To give just one example, the framework for the American Common Core Standards being developed by the National Academies of Science includes the following in its chapter on scientific practices:-

> *When considering the curriculum, it is important to consider the nature of the domain: Science is not only a body of knowledge that represents current understanding of natural*

[1] National Research Council. (2001). *Adding it up: Helping children learn mathematics*. J.Kilpatrick, J. Swafford, and B.Findell (Eds.) Washington, DC: National Academy Press. www.nap.edu/openbook.php?isbn=0309069955

systems; it is also the practices whereby that body of knowledge has been established and is being continually extended, refined, and revised. Both elements – knowledge and practices — are essential.

Chief among these is a commitment to evidence and data as the basis of developing claims. Therefore, argumentation and analysis that relate data and theory are essential features of science. [2]

Science is an empirical discipline. If students are to appreciate the nature of science, and where scientific knowledge comes from, it is important to involve them in the processes of scientific inquiry. A recent report from the Science Community Representing Education (SCORE) stated that:

The importance of practical work in science is widely accepted and it is acknowledged that good quality practical work promotes the engagement and interest of students as well as developing a range of skills, science knowledge and conceptual understanding[3].

2) *Science content specified in the National Curriculum should contain a balance of scientific concepts and processes. It should also specify practical work in terms of the essential understanding and competencies which need to be demonstrated by pupils.*

[2] Committee on Conceptual Framework for New Science Education Standards; *A framework for science education: preliminary public draft*; July 12-August 2, 2010

[3] SCORE (2008), *Practical work in science: A report and proposal for a strategic framework.* London: The Royal Society

16 a) Design and Technology

Design and technology is currently a compulsory National Curriculum subject, with a statutory Programme of Study, at Key Stages 1-3. In future, do you think design and technology should continue to be a National Curriculum subject?

√	Yes	☐	No	☐	Not Sure

16 b) If yes, please tick all key stages to which this should apply.

√	Key Stage 1 (5-7 years)	√	Key Stage 2 (7-11 years)	√	Key Stage 3 (11-14 years)
☐	Key Stage 4 (14-16 years)				

Nuffield's past role in the development of curricula and resources for Design and Technology, along with more recent work in cross-curricular STEM (science, technology, engineering and mathematics) projects has highlighted the importance of Design and Technology as a school subject.

With the current shortage of engineers in this country, it is important that pupils have the opportunity to experience how STEM subjects work together in this professional context. Design and technology can provide the relevant experience which brings together science, mathematics and the design processes which are key to producing successful future engineers. Currently, knowledge and understanding of design is absent from the curriculum of many potential engineers, who may specialize too early in mathematical subjects.

3) *Design and Technology should be given due prominence in the National Curriculum to ensure that pupils experience this important aspect of their STEM education.*

20 a) Modern Foreign Languages (MFL)

Modern foreign languages is currently a compulsory National Curriculum subject, with a statutory Programme of Study, at Key Stage 3 only. In future, do you think **modern foreign languages** should continue to be a National Curriculum subject?

√	Yes		No		Not Sure

20 b) If yes, please tick all key stages to which this should apply.

√	Key Stage 1 (5-7 years)	√	Key Stage 2 (7-11 years)	√	Key Stage 3 (11-14 years)
√	Key Stage 4 (14-16 years)				

The Nuffield Languages Inquiry (1998-2000) was established to review the UK's capability in languages[4]. The Inquiry's work was chaired by Sir Trevor McDonald and Sir John Boyd.

The Inquiry concluded that, in a smart and competitive world, exclusive reliance on English leaves the UK vulnerable and dependent on the linguistic competence and the goodwill of others. The inquiry found that the UK workforce suffers from a chronic shortage of people at all levels with usable language skills, to the extent that mobility of employment is in danger of becoming the preserve of people from other countries.

Schools and colleges do not provide an adequate range of languages and levels of competence for the future. There is a widespread public perception, backed by research, that learning another language needs to start earlier if the next generation is to achieve higher standards. An early start to language learning also enhances literacy, citizenship and intercultural tolerance. Currently, there is no rational path of learning from primary school to university and beyond, and this produces a vicious circle, where lack of supply of language teachers exasperates the situation.

4) *The importance of modern languages for the UK should be reflected in the current review of the curriculum.*

[4] http://www.nuffieldfoundation.org/nuffield-languages-inquiry-and-nuffield-languages-programme

SECTION F: SUPPORTING AND RECOGNISING PROGRESS (Q23a-Q26)

24. Within each Programme of Study, how should the curriculum and attainment targets be defined to ensure appropriate education for pupils in a wide range of circumstances as learners?

25 a) How do you think the needs of low-attaining pupils should be addressed through the National Curriculum?

25 b) How do you think the needs of high-attaining pupils should be addressed through the National Curriculum?

25 c) How do you think the needs of pupils with special educational needs and disability (SEND) should be addressed through the National Curriculum?

25 d) How do you think the needs of other specific groups of pupils should be addressed through the National Curriculum?

In response to 25d in particular, for mathematics and science, the question is not simply about pupil ability or attainment. Pupils need to access a curriculum which serves their future need for mathematics and science, regardless of their ability.

Science education for all

> *Science education is complex, and must serve two objectives. First, it must aim to increase the scientific and mathematical literacy of young people in general. Second, it must stretch and challenge those with the potential to become tomorrow's scientists.*[5]

The statement above, from a recent Royal Society report, reflects the view of the Nuffield Foundation. We would go further, to suggest that a single curriculum can't support the full range of important roles of science and mathematics education. From age 14, a choice of pathways is appropriate in both subjects.

Twenty First Century Science was the first attempt to provide a suite of GCSE science options. This course was designed in response to the then QCA's call for partners in development of a new science curriculum for first teaching in 2006. Underpinning the development is the Beyond 2000 report[6], which summarised a series of seminars involving top UK science education experts, and was funded by the Nuffield Foundation. The report recommends that, at key stage 4, the science curriculum needs to differentiate between the elements of

---

[5] The Scientific Century: securing our future prosperity, *Policy report*. London: The Royal Society. http://royalsociety.org/The-scientific-century/

[6] Osborne, J. and Millar, R. (1998), *Beyond 2000: Science education for the future*. London: Nuffield Foundation. http://www.nuffieldfoundation.org/sites/default/files/Beyond%202000.pdf

the curriculum needed to enhance scientific literacy, and elements which contribute to early training of future scientists.

The *Twenty First Century Science* course was developed by the University of York and the Nuffield Foundation, and was carefully piloted in over 80 schools. It is important to distinguish between this course and the more general changes to the science curriculum seen in 2006, which are often referred to collectively as *Twenty First Century Science.*

With a common core of scientific literacy, the *Twenty First Century Science* suite provides a model for post-14 science pathways. A scientific literacy qualification is provided in the single award GCSE. There is a choice of routes which build on the core for pupils who wish to achieve double award or triple award science, or a double award in applied science. GCSEs in single sciences (e.g. biology) are also possible.

The external evaluation of the *Twenty First Century Science* pilot [7] showed that, while there was no significant difference in the performance of pupils in questions testing understanding and application of science concepts, the performance of the *Twenty First Century Science* students in responding to questions about data and its limitations was stronger compared with the control group.

Attitudinal differences were also found between students following *Twenty First Century Science* and students following more conventional courses. *Twenty First Century Science* students were significantly more likely to find news items on science interesting, to report liking reading science books other than school science text books, to believe that the Government should spend more money on scientific research and to feel that it is important to promote this country as a scientific nation.

The pilot evaluation of *Twenty First Century Science* found that both teachers and pupils found the course "livelier, more relevant to citizens' lives and more interesting than traditional Double Award". Most schools found the learning outcomes of the Core Science course more demanding than traditional Double Award.

An analysis of the 2007 GCSE cohort carried out by Leeds University and funded by Nuffield, found that the proportion of *Twenty First Century Science* students progressing to at least one AS-level Science qualification was 17% higher than the corresponding proportion

[7] Donnelly, J. (2007), *Twenty first century science pilot evaluation report.* London: UYSEG and Nuffield Foundation. http://www.21stcenturyscience.org/data/files/c21-evaln-rpt-feb07-10101.pdf

for students following equivalent courses from other awarding bodies. This is a potentially significant finding, and corroborates the previous research by Professor Robin Millar published in School Science Review[8]. The follow-on research is as yet unpublished, but the Nuffield Foundation is continuing to fund research on further cohorts of pupils to see if this finding represents a consistent trend.

Science and mathematics pathways

As suggested above, we support the idea of a curriculum which provides a range of science and mathematics education pathways from the age of 14, according to pupils' particular interests and aspirations. This range is necessary to cater for the diverse needs of higher education, science and technology industries and basic mathematical, statistical and scientific literacy. If this structure is adopted it is essential that the likely progression routes attached to each pathway are transparent to students and parents.

In order to facilitate flexibility in the curriculum post-14, and in response to the specific questions in sections 10b and 11b in this consultation, we would support the idea of retaining KS1 and KS2 but simply having 'secondary' criteria for KS3 and KS4, with provision leading to pathways as discussed in this section.

A recent report published by the Foundation: *Is the UK an outlier?*[9] showed that in the UK (and in England and Wales in particular) rates of participation in mathematics beyond the age of 16 were greatly below those in other OECD countries. It is clear that the pathways currently available for mathematics in the UK are inadequate. Some students, aspiring mathematicians, physicists and engineers, for example, are relatively well catered for by A levels in Mathematics and Further Mathematics. But outside that there are very few options, with the result that in England over 80% of students in effect do no further mathematics after the age of 16. By any standards this puts us out on a limb.

In his report *Making Mathematics Count*[10] Adrian Smith recommended trialling a variety of pathways for 14-19 mathematics. He saw these:

> *not only as important steps towards improving the current structure, but also as contributing to a longer term direction of travel, compatible with the notion of progressive pathways, each with its own mathematical components. We see some version of the latter as the key to*

---

[8] Millar, R (2010), *Increasing participation in science beyond GCSE: the impact of Twenty First Century science.* School Science Review, 337, 67-74.

[9] Hodgen, J. et al (2010) *Is the UK an outlier? An international comparison of upper secondary mathematics education,* London. Nuffield Foundation.

[10] DfES, (2004). *Making Mathematics Count: The Report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*, www.mathsinquiry.org.uk/report/MathsInquiryFinalReport.pdf

providing a structure whereby all students have access to a relevant mathematics pathway appropriate to their learning needs, and relevant to end destinations in the workplace, or continuing education.

As the recent Wolf Report[11] points out, the role of restrictive funding policies and incentives has been to steer schools and colleges towards key skills, and, more recently, functional skills. Such restrictions should be ended to allow development of the range of innovative certificates and GCSEs which have been piloted on Smith's recommendation.

We recommend revisiting Adrian Smith's proposed studies of pathways. Given the successes of *Twenty First Century Science,* the curriculum review could consider a similar model for mathematics, with a core of mathematical literacy and pathways for using and applying mathematics and a deeper exploration of the subject.

Nuffield has a particular interest in the use of mathematics. We are also interested in the applied science route. In his report to the Nuffield Foundation *An invisible revolution?*[12] Jim Donnelly describes the rapid rise in number of students taking applied science. In 2008 nearly 110,000 students, some 15% of the age cohort, gained a GCSE or equivalent qualification in Applied Science. Five years earlier the number was less than 20,000. Some of these pupils chose the BTEC route, but most have chosen Applied Science. Donnelly's report provides convincing evidence that these students perform better taking Applied Science than they would have done had they followed the mainstream route. The distinctive pedagogy and content of applied science courses means these courses fulfil an important role for a group of students who learn more effectively through contextualised and practical work-based scenarios. The rise in pupil numbers shows there is a demand and need for a course of this type. The review should recommend that the needs of these students are considered.

Assessment

For governments seeking to improve education quality, a sound assessment policy is crucial. For school-level assessment to be effective, it should be consistent, regular and reliable, part

[11] http://www.education.gov.uk/publications/eOrderingDownload/The%20Wolf%20Report.pdf
[12] Donnelly, J. (2009), *An invisible revolution? Applied Science in the 14-19 curriculum* London: The Nuffield Foundation. http://www.nuffieldfoundation.org/applied-science-invisible-revolution

of an overall school development policy and feature both formative and summative assessments.[13]

.... Our view is that there can be no curriculum development without similar attention being paid to the development of appropriate mechanisms of assessment that have at least a benign effect on the curriculum. For the developers of new courses at GCSE, this means that a significant amount of their efforts must be devoted to producing assessment items that match the aims and objectives of the course.[14]

Studies have found that on one hand, assessment can be used formatively to help pupils' learning, but on the other hand, assessment systems relying on tests have a narrowing impact on teaching and on the curriculum and a negative impact on pupils' motivation for learning. Systems relying heavily on test results are found wanting in several respects, particularly in their ability to give a valid and reliable account of pupils' learning.

A study by Wynn Harlen[15] found that these effects need not follow if teachers have a greater role in summative assessment, using their knowledge of pupils to provide information relevant to the full range of goals of education – not just those easily tested. Nuffield supports the view that assessment reform is a vital part of any curriculum reform. Reform of assessment should refer to the considerable research in this field.

Nuffield has particular concerns about the current assessment of processes in science and mathematics. More work in this area is needed, to define suitable learning outcomes which then drive the desired curriculum, pedagogies and learning. If the curriculum is designed before the assessment rather than being considered in parallel development, designing suitable assessment is more problematic[16].

5) *The review should draw on the research on Twenty First Century Science (a GCSE curriculum project developed by the Nuffield Foundation and the University of York) as a model for GCSE pathways and content. In particular, the curriculum review should consider how the curriculum for science can fulfil the diverse needs of the full range of pupils.*

---

[13] UNESCO International Bureau of Education (UNESCO-IBE) http://www.ibe.unesco.org/fileadmin/user_upload/COPs/Pages_documents/Resource_Packs/TTCD/sitemap/Module_8/Module_8.html

[14] Osborne, J. F., Duschl, R. and Fairbrother, R. (2002), *Breaking the Mould: Teaching Science for Public Understanding*. London: Nuffield Foundation.

[15] Harlen, W. (2006), *The role of teachers in the assessment of learning*. London: Assessment reform group. http://www.nuffieldfoundation.org/assessment-systems-future

[16] Wiggins, G. and McTighe, J. (1999), *Understanding by Design.* . Alexandria, VA: Association for Supervision and Curriculum Development.

6) *The curriculum review should ensure the continuation and development of the applied science route and its progression pathways.*

7) *The National Curriculum should define a minimal core, but leave plenty of potential for a range of additional content.*

8) *A range of approaches for the different needs of pupils should be provided in the 14-19 science and mathematics pathways.*

9) *Summative and formative assessment should be considered as the content of the curriculum is reviewed. Assessment should be designed to drive teaching and learning through inquiry, practical work and discussion, which are essential to science and mathematics education.*

SECTION G: INTERNATIONAL COMPARISONS (Q27a - Q28)

27 a) Please give examples of any jurisdictions that could usefully be examined to inform the new National Curriculum. Please also briefly describe the reasons for the examples given.

27 b) Considering your response to question 27a above, what features of their national curricula or wider education systems are most significant in explaining their success?

28 Please use this space for any other comments you would like to make about the issues covered in this section.

Principled curriculum development

> *A formal procedure should be established whereby innovative approaches in science education are trialled on a restricted scale in a representative range of schools for a fixed period. Such innovations are then evaluated and the outcomes used to inform subsequent changes at national level. No significant changes should be made to the National Curriculum or its assessment unless they have been previously piloted in this way.* [17]

We welcome the curriculum review's stated aim to frame developments in a relevant evidence-base. Knowing that there is always a period of adaptation to major curriculum change, it is important to be sure that any changes to the curriculum are based on evidence of causal factors. For example, identifying and considering the nuanced reasons why UK pupils fall behind in PISA before using the current situation as evidence for the need for change.

[17] Osborne, J. and Millar, R. (1998), *Beyond 2000: Science education for the future*. London: Nuffield Foundation. http://www.nuffieldfoundation.org/sites/default/files/Beyond%202000.pdf

It is likely that the curriculum plays a relatively small part in the differences in performance between countries. Other factors such as socio-economic factors, teacher professional development or the amount of summative assessment pupils are subjected to are equally if not more significant. If there is an assumption that a rising ranking in PISA and TIMSS equates with rising standards, there is little evidence for this[18]. A number of studies have challenged the validity of rank ordering of countries through this type of standardised test.[19]

The Review makes clear that the UK should learn from best practice in other countries, and that we should aim to improve our position in international comparisons. We support these aims. The PISA measurements for Mathematics (2012) and Science (2015) are moving in directions that are consistent with the principles we have outlined above, and we applaud this.

In PISA 2012, mathematics will be the major domain to be assessed. The draft *PISA 2012 Mathematics Framework*[20] states 'The PISA 2012 framework is designed to make the mathematics relevant to 15-year-old students more clear and explicit, while ensuring that the items developed remain set in meaningful and authentic contexts. The mathematical modelling cycle, used in earlier frameworks to describe the stages individuals go through in solving contextualised problems, remains a key feature of the PISA 2012 framework. It is used to help define the mathematical processes in which students engage as they solve problems—processes that are being used for the first time in 2012 as a primary reporting dimension.'

Further, mathematical literacy provides 'the theoretical underpinnings of the PISA mathematics assessment'. It is defined thus:

---

[18] Askew, M. et al (2010), *Values and variables: Mathematics education in high performing countries*, p.11. Nuffield Foundation

[19] Tymms, P. (2004) *Are standards rising in English primary schools?* British Educational Research Journal, 30(4), 477-494.

Bonnet, G. (2002) *Reflections in a critical eye: On the pitfalls of international assessment. Knowledge and skills for life: First results from PISA 2000.* Assessment in Education, 9(3), 388-399.

Schagen, I. and Hutchison, D. (2003) *Adding value in educational research - the marriage of data and analytical power.* British Educational Research Journal, 29(5), 749-765.

Hilton, M. (2006) *Measuring standards in primary English: issues of validity and accountability with respect to PIRLS and National Curriculum test scores.* British Educational Research Journal, 32(6), 817-837.

Shiel, G. and Eivers, E. (2009) *International comparisons of reading literacy: what can they tell us?* Cambridge Journal of Education, 39(3), 345-360.

[20] OECD. (2012). *PISA 2012 mathematics framework* www.oecd.org/dataoecd/8/38/46961598.pdf

….. mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens.

For the purposes of the PISA assessment, mathematical literacy is analysed in terms of three inter-related aspects: the mathematical content that is targeted for use in the assessment items; the mathematical processes and the capabilities that underlie those processes that describe what individuals do to connect the context for the problem with the mathematics to solve a problem; and the contexts in which the assessment items are located.

Other countries acknowledge the importance of mathematical literacy explicitly in their National Curricula. For example, the American Common Core Standards for mathematics put forward eight standards for mathematical practice, building on the five strands of mathematical proficiency mentioned earlier and on the process standards of the US National Council of Teachers of Mathematics – of problem solving, reasoning and proof, communication, representation, and connections. It is clear that realizing any aim to improve the UK 's status in international comparisons must involve characterizing the processes of mathematics and science in the curriculum.

At an early meeting of the expert group who will advise on the PISA framework for the science tests in 2015, it was agreed that future tests should provide broader and richer assessment than the limited measures of competencies in the existing framework. A number of countries that currently do well in PISA have concerns about the ability of their pupils to think for themselves rather than learn facts effectively. The 2015 tests will include areas of science knowledge categorised, for example, as conceptual (e.g. scientific theories), procedural (e.g. knowledge of how to engage in inquiry) and epistemic (e.g. knowledge of what a theory is).

10) *The UK curriculum needs to align itself with future developments rather than looking back. The curriculum review should consider carefully the directions that are emerging from the plans for future PISA tests to ensure that UK does not fall behind in international comparisons as a result of moving the mathematics and science curricula in a different direction.*

SECTION H: HOW CHILDREN LEARN (Q29)

29 What research evidence on how children learn provides the most useful insights into how particular knowledge should best be sequenced within the National Curriculum Programmes of Study?

If drawing on particular research evidence, please provide a brief summary of the evidence, with a reference or web address to key studies or research summaries.

Evidence for how children learn in mathematics and science

The *Key understandings in mathematics learning*[21] study directly addresses the issue of how pupils learn for primary mathematics education. A related project is underway for secondary mathematics[22].

A key finding in the first study is that one cannot separate the different aspects of content and that making connections is an essential element of mathematics. Further, the report states

> *… the fact that students use intuitive models when learning mathematics, whether the teacher recognises the models or not, is a reason for helping them to develop an awareness of their models. Students can explore their intuitive models and extend them to concepts that are less intuitive, more abstract. This pragmatic theory has been shown to have an impact in practice.*

On a related note, the US National Research Council report *Adding it up*[23] stresses 'the importance of adaptive expertise and of what is called metacognition: knowledge about one's own thinking and ability to monitor one's own understanding and problem-solving activity'. It is important that these overarching principles are borne in mind when designing the curriculum.

Effective approaches to learning

Revisions to the National Curriculum should consider the evidence from educational research, neuroscience and cognitive psychology to suggest how the statutory curriculum and assessment can stimulate effective approaches to learning.

---

[21] Nunes, T., Bryant, P., and Watson, A. (2008), *Key understandings in mathematics learning.* London: Nuffield Foundation. www.nuffieldfoundation.org/key-understandings-mathematics-learning

[22] *Guidance on teaching key ideas in secondary mathematics* (2010-2011), Professor Anne Watson, University of Oxford, Professor Dave Pratt, Institute of Education, Keith Jones, University of Southampton. www.nuffieldfoundation.org/guidance-teaching-key-ideas-secondary-mathematics

[23] Kilpatrick, J.; Swafford, J.; Findell, B. (2001), *Adding It Up: Helping Children Learn Mathematics.* Washington: Centre for Education.

For example, learning in science involves familiarity with current scientific practices, including inquiry. This is much more than rote mastery of skills. It involves simultaneous coordination of knowledge and skills. Skills and their assessment need to be better defined, along with the range of cognitive, social, and physical practices that scientific inquiry involves.

The large and constantly growing body of knowledge in science can easily lead to a curriculum which is overloaded with facts. Constructivist theories suggest that pupils should be encouraged to build overarching, reusable scientific principles[24]. These should be applied in a range of contexts to develop deep understanding. Without these principles, learners have no framework for solving future problems, or on which to 'hang' scientific 'facts'.

Better coordination across subjects could facilitate more effective learning. Lack of coordination of mathematics and science in particular does not currently allow these subjects to support each other effectively.

STEM

> *I would say that [the Nuffield STEM project] was hugely successful…… On the first day of the two days I went round and spoke to students. The projects were not superficial and they were fully engaged. I asked students about the bridging between subjects – had they used the skills – [they were] surprised that they had, but when they thought about it they had. This was a departure from normal lessons.*
>
> *A senior manager in a STEM specialist school in London, observing the piloting of the Nuffield STEM project, Futures.*

The opening up of the curriculum at Key stage 3 from September 2008 led to Nuffield's recent work in cross-curricular STEM. The organization of curriculum topics with cross-cutting themes provided a stimulus for interesting contextualized learning, and consideration of common knowledge and skills across subject areas.

The curriculum should continue to encourage collaboration across subject areas, as teachers can learn approaches and content knowledge through better inter-departmental communication. Up to age 14 at least, the curriculum should also encourage consideration of important cross curricular themes such as sustainable development, and their treatment from the point of view of the different school subjects.

---

[24] Leach, J., Scott, P. (2002) *Designing and Evaluating Science Teaching Sequences: An Approach Drawing upon the Concept of Learning Demand and a Social Constructivist Perspective on Learning.* Studies in Science Education, 38 (1), 115-142.

11) *The curriculum review should consult widely with the educational research communities to ensure a curriculum based on a sound, evidence based educational framework.*

12) *We recommend the review takes the opportunity to coordinate the curriculum and highlight cross-curricular links to allow related subjects to support and reinforce each other.*

SECTION J: IMPLEMENTATION (Q34 - Q35)

34. What are the particular issues that need to be considered in phasing the introduction of the new National Curriculum in the way proposed, with Programmes of Study in some subjects introduced in 2013 and the rest a year later?

35. What other arrangements, if any, need to be considered in implementing the new National Curriculum, and how they should be addressed?

Teacher professional development

Teacher professional development will be key to the successful implementation of the new National Curriculum.

13) *The Review should consider carefully the transition to the new National Curriculum. Existing organisations such as the National Network of Science Learning Centres and HEIs which engage with schools should continue to be supported to provide a continuing programme of teacher professional development.*

Here at the Department for Education we carry out our research on many different topics and consultations. As your views are valuable to us, would it be alright if we were to contact you again from time to time either for research or to send through consultation documents?

[√] Yes [ ] No