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Research Review Series: Science

Introduction and background

At the end of March, Ofsted announced its intention to carry out a series of research reviews to examine what published research evidence says about a high-quality education in each subject. It is hoped that the reviews will support and inform those leading the thinking on subject education in schools.
This first review explores the literature relating to the field of science education. Its purpose is to identify factors that can contribute to high-quality school science curriculums, assessment, pedagogy, and systems. Ofsted will use this understanding of subject quality to examine how science is taught in England's schools. It will then publish a further report in 2022, presenting what has been learned.

Key findings

Science education: Context

- A science education forms an important entitlement for all young people. It enables pupils to explain the material world and develop a sense of excitement and curiosity about natural phenomena. An understanding of scientific enquiry enables pupils to appreciate the nature and status of scientific knowledge, knowing it is open to revision in the light of new evidence.
- Pupils also learn about the significance of science to their own lives and to society, looking, for example, at the eradication of diseases, and at current global challenges.
- Science education provides the foundation for a range of diverse and valuable careers that are crucial for economic, environmental, and social development.
- Pupils begin their formal science education in the early years foundation stage (EYFS), where they learn foundational knowledge through the 'understanding the world: the natural world' area of learning.
- At primary school, there is a science curriculum outlining what pupils should learn. However, there is concern that science is being squeezed out of the curriculum. In February 2019, an Ofsted report, 'Intention and substance: primary school science curriculum research' reported that in most primary schools, disproportionate amounts of curriculum time were being spent on English and mathematics, significantly reducing the amount of curriculum time available for science, In the 2018 biennial national science tests, just 21.2 per cent of the year 6 pupils tested were estimated to have reached the expected standard in science.
- Results from a 12-year longitudinal study (Novak and Musonda, 1991) show why weaknesses in primary science education are an issue. They found that early introduction to science concepts in primary school positively influences subsequent science learning throughout secondary school and minimises misconceptions.
- At secondary level, a high proportion of pupils (95%) were entered for EBacc science in 2019, and 26 per cent were entered for triple science. The numbers of pupils studying science subjects at A level are encouraging. However, recent findings from TIMSS 2019 show that England's performance in science at Year 9 has decreased significantly compared with 2015, albeit remaining well above the TIMSS average. Of particular concern is the widening gap between the highest- and lowest-performing Year 9 pupils in science.
- Schools face several challenges in science recruitment. Although in 2019 the number of trainees specialising in biology exceeded the Department for Education's recruitment target, chemistry and physics recruitment reached only 70 per cent and 43 per cent of target, respectively. The 2019 school workforce census shows that 26.6 per cent of teaching hours in physics were taught by teachers with no relevant post-A-level qualifications. The figure was 17.3 per cent and 6.9 per cent for chemistry and biology, respectively.

The science curriculum

- The school science curriculum sets out what it means to make progress in science. Pupils need to develop an extensive and connected knowledge base, organised according to major scientific principles. When they acquire

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new knowledge, it should become integrated with the knowledge they already have – this makes the learning meaningful.
- Pupils need to build at least 2 forms of science knowledge. The first is 'substantive' knowledge, which is knowledge of the products of science, such as models, laws, and theories. The second category is 'disciplinary knowledge', which is involves learning how scientific knowledge becomes established and gets revised. Disciplinary knowledge of scientific enquiry, which forms a curricular goal, should not be confused with enquiry-based teaching approaches. It needs to be explicitly taught.
- In high-quality science curriculums, knowledge is carefully sequenced and balanced to show the interplay between substantive and disciplinary knowledge. This ensures that pupils not only know 'the science'; they also know the evidence for it and can use this knowledge to work scientifically.
- Expertise in science is associated with being able to connect knowledge between different levels when thinking about problems. This might, for example, involve explaining what is happening at the cellular level by referring to what molecules are doing at the submicroscopic level.
- The curriculum should break down complex concepts and procedures into meaningful 'chunks' of content which can be sequenced in the curriculum over time without overloading working memory.
- Scientific processes such as observation, classification, or identifying variables should always taught in relation to specific substantive knowledge, and not seen as generalisable skills. For example, classifying flowering plants scientifically requires knowledge of floral parts to place specimens in appropriate groups.

Organising the curriculum: elements of a high-quality curriculum

- In the early years, pupils are introduced to a wide-ranging vocabulary that categorises and describes the natural world. These words are not too technical but provide the 'seeds' for developing scientific concepts that will be built on in later years.
- Top-achieving countries in TIMSS use the principle of 'curriculum coherence' to organise their national science curriculums. This involves teaching topics – and the substantive content within them – in a particular sequence that reflects the hierarchical structure of the scientific disciplines.
- Substantive knowledge is sequenced so that, throughout their schooling, pupils build their knowledge of important concepts such as photosynthesis, magnetism, and substance throughout their time at school. As they progress through the science curriculum, new knowledge gets systematically integrated into pre-existing knowledge. This forms larger concepts and new ones, which in turn allow pupils to operate at more abstract levels.
- All resources need to be carefully matched to curriculum intent, though the easy availability of online resources means that subject leaders should take extra care to ensure that they are not used in a piecemeal fashion.
- Science kits can encourage teachers to be too activity-based, rather than teaching and developing the underlying scientific concepts the activities were designed to teach.
- High-quality science textbooks can give clear delineation of content with a precise focus on key concepts and knowledge. They also provide a coherent learning progression within the subject.

Practical work: elements of a high-quality curriculum

- The purpose of practical work is clear in relation to curriculum content so that practical activities can be set up and managed to develop pupils' disciplinary and/or substantive knowledge.
- Practical activities form part of a wider instructional sequence that gives pupils time beforehand and afterwards to connect theory to observation. Pupils have the necessary prior knowledge to learn from the activity.
- Through both laboratory and fieldwork, pupils move beyond their everyday experiences to develop a sense of wonder and curiosity about the material world.

Science pedagogy and assessment: elements of a high-quality curriculum

- Activities are carefully chosen to match specific curriculum intent. Teachers use carefully sequenced explanations, models, analogies, and other representations to help pupils to acquire, organise, and remember scientific knowledge. Analysis of pupil responses and outcome data from PISA 2015 reveals that teacher-directed science instruction is positively associated with science performance in almost all countries.
- Planning and teaching takes account of the limited working-memory capacity of pupils.
- Pupils are not expected to arrive at scientific explanations by themselves without sufficient prior knowledge.
- Systematic approaches, alongside carefully selected texts, are used to teach the most important vocabulary in science from an early stage.
- Assessment is not overly burdensome on teachers' time in relation to marking, recording or feedback.
- Feedback is focused on the science content and not on generic features.
- Pupils regularly retrieve knowledge to help them remember and organise their knowledge. Teachers think carefully about what pupils are being asked to retrieve and whether this prioritises the most important content.
- Overuse of external assessment items, such as GCSE or A-level questions, is avoided because this narrows the curriculum.

Elements of effective systems

- Teachers, teaching assistants and technicians have access to high-quality subject-specific CPD.
- Timetables at both primary and secondary level allocate appropriate teaching time to science, reflecting its status as a core subject in the national curriculum.
- Primary schools have at least one teacher who specialises in teaching science and science leaders have dedicated leadership time.

The full document can be downloaded from:

https://www.gov.uk/government/publications/research-review-series-science/research-review-series-science