From option to compulsion: school science teaching, 1954–2004

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The last fifty years have seen considerable change in science education, but for the science teacher much remains the same

In 1954, secondary education within the United Kingdom was selective. In grammar and public schools, science teaching was dominated by the needs of the relatively new O- and A-level examinations of the General Certificate of Education (GCE), introduced in 1951. Unlike the School Certificate and Higher School Certificate examinations that they replaced, GCE examinations were subject, rather than group, based. In addition, a pass at O-level was equated with a pass with credit in the former School Certificate examination. The numbers of candidates entered for GCE examinations were small, although they rose steadily throughout the 1950s and beyond, as more pupils entered the education system and stayed longer within it (see Table 1).

As Table 1 makes clear, entries for O-level general science failed to keep pace with the rate of increase in the numbers of candidates for physics, chemistry and biology. The expansion of school biology teaching, from a relatively low base in the case of boys, is particularly noteworthy. So, too, are the relative numbers of entries in physics and chemistry for girls and boys. When compared with the gender distribution among all O-level entrants, girls were considerably 'under-represented' in these subjects as well as in mathematics. In some schools, including coeducational schools, girls were effectively 'debarred' from a full science course in the sixth form because they had done virtually no physics or chemistry in the main school or because they had failed, or did not take, mathematics at O-level. In 1962, for example, only 40 per cent of the girls' grammar schools in England taught *any* physical science in the fifth year, a figure which fell to nearer 20 per cent when general science was excluded. This is despite the fact that the twenty or so years following the end of the Second World War were particularly rich in opportunities for recruitment to science-based careers. The achievements of science in the conduct of that war, the introduction of civilian jet transport, the discovery of the structure of DNA, the opening of the world's first nuclear power station at Calder Hall and the launch of *Sputnik* were among many developments that promised an optimistic, science-based future. That future was not yet darkened by the problems exposed in Rachel Carson's *The silent spring* (1962) or by other threats to the environment that have now become so familiar. Remarkable though it seems from today's perspective, competition for university places in science (but not engineering) was intense.

ABSTRACT
Fifty years ago, only a small minority of secondary school pupils in the UK received a broad and balanced science education, and science in primary schools was largely confined to nature study. This article outlines some of the political, administrative, and curriculum initiatives that have led to the present commitment to science for all.

The replacement of the School Certificate examinations by the General Certificate of Education had little initial effect on the form and content of the examination papers. Those in physics remained

Table 1 GCE O-level entries, 1951, 1955 and 1962, by subject and gender.

Year	*General science*		*Physics*		*Chemistry*		*Biology*	
	Boys	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
1951	12 538	9134	18 819	2729	16 005	4672	6935	22 079
1955	15 359	9811	32 495	4662	28 044	6910	12 872	34 080
1962	15 076	9683	67 986	11 705	52 498	14 893	25 689	73 842

divided into sections with such titles as ‘Electricity and magnetism’ and ‘Heat, light and sound’. Imperial units prevailed and the emphasis was exclusively upon classical physics. Questions on botany and zoology were still readily detectable in biology examinations and the influence of medical education upon the school biology curriculum remained strong, especially in the importance attached to dissection at A-level. In chemistry, the emphasis was on the preparation, properties and industrial manufacture and uses of materials, with A-level students also being required to prepare a wide range of organic compounds and to become competent at volumetric and systematic qualitative analysis. The following examples show how little had changed in the case of chemistry examinations, although equally striking examples could be cited for school physics:

> *How would you prepare and collect hydrogen sulphide, using ferrous sulphide? Sketch the apparatus you would employ. What is the action of hydrogen sulphide on (a) sulphur dioxide, (b) an aqueous solution of caustic soda, (c) an aqueous solution of lead nitrate?*
> (School Certificate, 1927, NUJMB)

> *How would you prepare and collect hydrogen sulphide? How, and under what conditions, does hydrogen sulphide react with (a) lead nitrate, (b) chlorine, (c) sulphur dioxide?*
> (O-level, Summer 1962, NUJMB).

Given questions of this type, it is hardly surprising that grammar school science teaching placed an emphasis upon the recall of factual information and the solution of relatively routine problems, including those that required numerical calculation. Definitions and principles were precisely worded and frequently to be ‘learnt by heart’. Demonstration experiments were widely used and pupils spent much time making accurate notes, often in a format that had been standardised for over half a century.

Compared with grammar and public schools, much less is known about the science taught to pupils in the secondary modern schools, which provided an education for the majority of pupils. There is a variety of reasons for this, including the absence of an appropriate national examination and the lack of extant information about the courses that were developed in individual schools, often in response to the perceived needs of local industry. Between 1944 and 1960, successive post-war Ministers of Education refused to sanction a national examination of a lower level than the GCE. As a result, many secondary modern school pupils were entered for examinations conducted by the College of Preceptors, the Royal Society of Arts or the Union of Educational Institutions, or organised by local education authorities in conjunction with groups of secondary modern schools for which they were responsible. The result, inevitably, was great diversity in the curricula of secondary modern schools, with some working initially at a level little, if at all, beyond that which they had reached as public elementary schools. Many others attempted, in difficult circumstances, to provide a good general education that focused on the interests of the pupils, rather than on the traditional subjects of the secondary school curriculum. In these schools, the school science curriculum was frequently organised on the basis of projects or topics with such titles as ‘Science in the home’ or ‘Science in our daily lives’. In contrast, parental and other pressure to seek ‘parity of esteem’ with the grammar schools prompted some secondary modern schools to adopt a more academic approach to their work. Such schools, however, were always a minority and the numbers of entries for O- and A-level examinations from modern schools were always small, especially at A-level. In 1961, for example, physics entries by boys at these two levels were 2345 and 9 respectively, with the corresponding figures for girls being 53 and 0. In chemistry, the numbers of entries by boys in the same year were 277 and 2 (girls

46 and 0), and, in biology, 418 and 3 (girls 2716 and 5). More is involved here than the familiar 'unpopularity' of physics as a subject of choice for girls. Many girls left school at 15, then the statutory school leaving age, to enter directly into local employment, followed within a few years by early marriage. In these circumstances, school physics and chemistry were seen by many modern schools as much less relevant to their needs than courses in human biology or domestic science. In addition, secondary modern schools suffered even more severely than the grammar schools from the post-war shortage of science teachers. While many grammar schools complained that they were being forced to appoint non-graduates to their staff to teach science, some secondary modern schools had no qualified science teachers at all. In 1957, for example, the 877 secondary modern schools providing O-level courses had 89 unfilled posts, 152 new posts to be filled, 177 filled unsatisfactorily and a total of 1375 non-graduates, many of them emergency-trained, teaching science. A year later, the headmistress of a girls' grammar school admitted that her school had been *'without a chemistry and physics mistress for some years'*.

In most cases, those teaching science in secondary schools, of whatever type, had little or no adequate technical assistance and most were forced to struggle along with the part-time help of untrained students. Being a school laboratory technician was seen as a blind-alley occupation. Training courses remained undeveloped, despite the efforts of the Science Masters' Association and the Association of Women Science Teachers to remedy the situation by developing an appropriate qualification in association with the City and Guilds of London Institute.

In primary schools, as elsewhere, what can be achieved with pupils is critically dependent upon the knowledge and expertise of those who teach them. Among primary school teachers, that knowledge and expertise remained inadequate for much of the twentieth century. Until the introduction of the National Curriculum and with the exception of those schools involved in the curriculum initiatives of the 1960s and '70s, the only science taught to most primary school pupils in England and Wales was 'nature study'. Regrettably, recognition that 'nature' had a physical as well as a biological dimension was slow to develop among primary school teachers, despite some pioneering efforts during the later 1950s.

Administrative reform

The 1960s were a period of significant change in many aspects of education. The publication in 1963 of the Robbins Report on Higher Education led quickly to the creation of several new universities. It also paved the way for teacher training colleges to develop closer academic links with local universities and provide degree opportunities for their more able students. A number of technical colleges, recently reorganised following the White Paper on technical education in 1956, became polytechnics, offering degrees awarded by the Council for National Academic Awards. Circular 10/65 confirmed the Government's intention to introduce in England and Wales a non-selective system of secondary education, although progress towards this objective was contested and large-scale change did not take place until the following decade. In 1964, amid complaints of the 'Prussianisation' of English education, Government created the Schools Council for the Curriculum and Examinations, whose Science Committee was to be particularly active in its attempts to reform school science curricula.

The publication of Circular 10/65 and the development of a publicly funded comprehensive system of secondary education required the accommodation of two different traditions within post-primary science education in England and Wales. The first, and by far the longer-established and stronger tradition, was essentially academic, in the sense of being strongly influenced by the demands of the universities and associated with the work of the grammar and independent schools. The second, much weaker and perhaps hardly amounting to a tradition, was pupil – rather than discipline – centred, concerned more immediately and directly with future employment, and associated with secondary modern schooling and its pre-1944 predecessors. The necessary accommodation was found, at least to a degree and in the short term, within two systems of public external examinations that emerged after the Government accepted the recommendations of the Beloe Report published in 1960. The Certificate of Secondary Education (CSE) examination was introduced in 1965. It was available in one of three modes, the third of which allowed teachers, subject to external moderation and other procedures, to devise their own syllabuses, examine their own pupils and award appropriate grades. Responsibility for administering the CSE examinations lay with fourteen newly created

Examination Boards, operating on a regional basis. These examinations co-existed with the longer-established GCE while teachers, policy-makers, parents and pupils all struggled to relate a pass in the one examination to performance in the other.

From 1965 onwards, therefore, secondary school science teachers, especially those teaching in modern and comprehensive schools, were given a remarkable degree of freedom over their own work. Interestingly, this was much greater in the case of pupils of lower educational achievement than for their more able peers, upon whose course of study GCE examinations remained a determining influence. The numbers of candidates entered for CSE examinations grew steadily, although less rapidly in science than in a number of other subjects. Perhaps not surprisingly, most candidates were entered under the mode 1 procedure, in which teachers prepared candidates for an externally prescribed CSE syllabus and an externally marked examination. Table 2 shows the CSE entries in science subjects in 1985 by mode and gender.

Four other features of the CSE examination are worthy of note. The first is the emphasis placed upon coursework, that is work undertaken by pupils, ostensibly as an integral part of the teaching and learning process, and commonly assessed by teachers. In the case of science, such coursework took the form of practical work undertaken in the laboratory or, less often, of projects or fieldwork. The second is that, like its GCE counterpart, the CSE examination showed a marked gender differential in the pattern of entries. Thirdly, unlike the GCE O-level examination, the CSE examination abandoned the concept of passing and failing in favour of grades recorded on certificates as 1, 2, 3, 4, 5 or U (ungraded). Finally, the arrangements for the CSE examination encouraged experimentation in techniques of assessment, including oral assessment in science, and, in a variety of ways, developed teachers' skills as curriculum designers, examiners and moderators.

The curriculum development era

In April 1962, the Minister of Education, Sir David Eccles, told the House of Commons that the Nuffield Foundation had decided to make available £250,000 towards the cost of a long-term development programme to improve the teaching of school science and mathematics. It was an announcement that marked the beginning of what has been called the curriculum development era, characterised by a world-wide attention to the reform of school science education. In the UK, the outcome of what quickly became known as the Nuffield Science Teaching Project was envisaged as a coordinated set of curriculum resources that teachers could use as they wished. In the first instance, attention was focused upon physics, chemistry and biology for 11–16 year-old pupils in grammar schools and streams, but these O-level projects were followed by others in mathematics, secondary science, combined science, junior science and A-level physics, chemistry, biology and physical science. The Nuffield Junior Science Project, approved by the Trustees of the Foundation in 1963, served to highlight how much needed to be done to establish science as a component of the primary curriculum. This task fell to the Schools Council Science 5–13 Project, funded jointly by the Council, the Foundation and the Scottish Education Department.

In all of these projects, science teachers were at the centre of the development process. Typically, a full-time project organiser was appointed to work with a project team, drawn, in most cases, from schools on a full- or part-time basis. A wider perspective was provided by a consultative or advisory committee,

Table 2 CSE entries in science subjects, 1985, by mode and gender.

Subject	*Mode 1*		*Mode 2*		*Mode 3*	
	Boys	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
Physics	107 395	31 244	1955	625	5933	1529
Chemistry	61 489	49 675	2037	630	7828	690
Biology	57 899	128 816	543	1102	6413	13 775
General science	19 633	14 999	1115	815	27 436	23 148

appointed to represent the views of higher education, academic science, local education authorities and others with a legitimate interest in science curriculum reform. The various projects produced a range of materials that were piloted in schools and subjected to critical review. The materials that survived this process included not only texts such as *Teachers' guides* but also 8 mm film loops and apparatus specially designed for teaching purposes. Commercial publication of these materials led to a demand for in-service training that was met in a variety of uncoordinated ways. Large numbers of teachers' centres were set up to meet that demand and over 600 such centres existed by the early 1970s. Many of these were LEA-based but, in the case of science, specialist centres were set up, usually within, or in close association with, institutions of higher education. In addition to helping disseminate project ideas and materials, these centres enabled science teachers to share professional experience and supported them in exploiting the flexibility in curriculum planning accorded to them by the introduction of the CSE examination.

As the project organisers themselves recognised, no attempt to reform the school science curriculum could succeed without reform of the examination questions that pupils were required to answer. Syllabuses specified aims and objectives in terms that owed much to Bloom's *Taxonomy*, and different types of questions, such as objective and short-answer questions, were introduced. At A-level, project work formed part of the overall assessment.

The curriculum development era also saw science education institutionalised as a field of enquiry and teaching within higher education in the UK. Chairs and higher degree courses in science education were established, along with the associated scholarly apparatus of new professional and research journals. These courses, with secondments financed by funds drawn from the LEA 'pool', were to play an important role in science teachers' professional development until this funding arrangement was abandoned in the mid-1980s.

In many ways, science teachers in the 1960s and 1970s were working within an educational free market. They were free, at least in principle, to choose from a range of syllabuses or, subject to constraints, construct their own courses and examine their own pupils for public certification. They were also free to adopt, ignore or select from the growing range of textual and audio-visual material and apparatus produced by a variety of curriculum initiatives. They had unparalleled opportunities for professional development and faced a barrage of texts and supporting materials from commercial publishers, all of which reflected the contemporary commitment to 'science by investigation'. For much of the 1960s, a distinction was drawn between 'Nuffield' schools, that is, those using Nuffield project materials and entering pupils for the special Nuffield examinations set by the Examination Boards, and other more 'traditional' schools which had not adopted project materials. By the mid-1970s, however, most O- and A-level GCE syllabuses and examinations had been revised to take account of the science curriculum initiatives supported by the Nuffield Foundation and the Schools Council. Many schools made substantial use of project materials, including apparatus, without wishing to enter their pupils for the special examinations developed by that project. Apparatus and equipment that had been the staple of school science teaching since the nineteenth century, such as Fletcher's trolley, Kipp's apparatus, glass retorts, dip circles, tangent galvanometers and Kundt's tubes, were all discarded, only to surface later in antique shops or the catalogues of specialist dealers in scientific instruments.

For some commentators, the failure of many schools to embrace wholeheartedly the curriculum and assessment initiatives was disappointing. However, there is no doubt that all the project materials were offered to science teachers as resources to be used in varying degrees, or not at all, in accordance with their professional judgement. The evidence suggests that science teachers responded in precisely this way and that their response reflected the significant differences that existed between schools, pupils and science teachers.

Acknowledgement of those differences, and of the consequent need to allow science teachers the freedom to devise courses that they judged met the needs of their pupils, lay at the heart of the Secondary Science Curriculum Review (SSCR) established in 1981. Equally important was the need to revisit the case for science in general education in the light of the changes that had taken place in the previous decade. In 1973, the school leaving age was raised to 16, and throughout the decade comprehensive secondary education became the norm in many local education authorities. The challenges presented by these developments to both secondary modern and grammar school science teachers were often formidable. Most comprehensive schools, and the science departments within them, were considerably larger than the grammar and modern schools from which they were formed. The two systems of examination at 16+, GCE and CSE, remained and it became necessary to make decisions about the entry of pupils for one or other, or occasionally both, of them. On 1 April 1975, the Health and Safety at Work Act 1974 brought schools within the compass of legislation comparable to that governing other areas of employment in the UK. Equal opportunities legislation introduced in 1975 outlawed curriculum discrimination between boys and girls. Secondary schools, as never before, found themselves seeking to identify the kinds of science course, or courses, that could best meet the needs of all their students when the professional experience of most of those teaching within them had been confined to only part of the age cohort. New courses, new teaching strategies, and new strategies for organising and managing schools and science departments within them seemed to be necessary.

The SSCR went through three phases – research, development and dissemination – and lasted until 1989. Emphasis was placed on setting up local working groups, centred upon local education authorities, each charged with developing curriculum resources in accordance with four criteria. These required that attention be given to: extending the educational opportunity for all pupils to study science; issues of progression and cognitive growth; matching learning objectives with teaching strategies and the abilities and expectations of pupils; and provision of extension studies for those with particular interests, abilities or difficulties. The work of the SSCR had a significant impact on the Government policy statement for school science published in 1985. Although the commitment in that statement to ‘a broad and balanced science for all’, including pupils of primary school age, did not originate with the SSCR, the SSCR did much to alert science teachers to some of the shifts that were taking place, at a variety of levels, about the form and content of school science teaching. The SSCR explored such issues as multicultural education and science for people with special educational needs, issues which faced many teachers in comprehensive schools but had hitherto received little attention. By helping to fund the Children’s Learning in Science Project, the SSCR also promoted a ‘constructivist’ perspective on learning and its implications for the ways in which science should be taught. The SSCR, together with the changes that had prompted it, also presented challenges for the Association for Science Education. With its origins in grammar and public schools, the Association had to respond to the concerns of the increasing proportion of its members working in comprehensive schools and, subsequently, to the issues surrounding the development and implementation of the National Curriculum, including the development of primary science.

As with the Nuffield and Schools Council science curriculum projects, the SSCR placed science teachers firmly at the centre of the reform process. Even by the time the SSCR was formally established, however, there was growing evidence that the political climate towards education was changing. If teacher-centred initiatives of this kind failed to raise school standards, increasingly demanded by Government after Prime Minister Callaghan’s Ruskin College speech in 1976, how might the necessary large-scale reform be achieved? In 1988, the answer came in the form of legislation.

Statutory entitlement and accountability

Between 1977 and 1985, a succession of documents from HM Inspectorate and from Central Government gradually made clear the direction of official thinking about the school curriculum. Concerns about standards, teaching methods, wasteful duplication, lack of accountability, inadequate courses and a lack of agreed objectives all pointed towards the need for a national curriculum entitlement, planned as a continuous and coherent whole throughout compulsory schooling and based upon the notions of breadth and balance. The Government’s intentions, set out by Secretary of State Sir Keith Joseph in a speech in 1984, were to form the basis of what became the Education Reform Act 1988 and the National Curriculum in England and Wales. Not surprisingly, it proved much easier to establish by legislation the principle of a national curriculum than to define its substance, implement it in schools or develop a clear and satisfactory relationship with teachers and their work. Throughout the 1990s, science teachers struggled to give substance to the Government’s prescription, with the first attainment target (AT1/Sc1) being a source of particular and enduring difficulty, despite a series of major revisions of the curriculum. The statutory creation of a new school subject ‘science’, from an amalgamation of scientific disciplines with different curriculum histories, methodologies and pedagogies, led to a rapid decline in entries in physics, chemistry and biology in the GCSE examination that had replaced CSE and O-level in 1988. Between 1989 and 1996, for example, the 197,000 entries in GCSE physics had fallen to 18,000 while, during the same period, science entries rose from 142,000 to almost half a million. In contrast, primary school science, despite initial anxieties, flourished, and can be accounted a significant achievement of the legislative process.

Overview

Any short account of school science teaching necessarily omits much. Examples are developments in laboratory design, shifts in terminology and teachers' perception of their role and status, the growing importance attached to international comparative studies of achievement such as TIMSS and PISA, the enduring issue of 'standards', theories of learning that underpin or justify practice, and changes in teacher–pupil relationships stemming from broader shifts in the society that schools seek to serve. It would also be easy to place too much emphasis upon more recent developments, notably the National Curriculum and its impact on science teachers' work. It is important, therefore, to acknowledge that, while the scale of that impact is probably without parallel, some form of change has been the norm, rather than the exception, in the history of school science teaching. The achievements of the science curriculum reform era and the inventiveness and commitment of the science teachers that made them possible should not be overlooked. Nor, too, should the way in which science teachers have responded to the demands and opportunities presented by developments such as the emergence of a system of comprehensive secondary education, the introduction of the CSE and GCSE examinations, and, more recently, of electronic forms of communication as a resource to support teaching and learning. Primary school science has been transformed, and more science, characterised by 'breadth and balance', is now being taught to more pupils than at any time in history. The management and organisation of schools and of science departments within them, have also changed, with heads of department having a wider range of responsibilities than ever before, many stemming from the demands of safety legislation, record keeping, inspection and accountability. The key role played by many science departments in the now compulsory initial training and induction of science teachers should also be noted. Historically, few secondary school teachers embarked upon a course of professional training; knowledge of subject matter was deemed a sufficient preparation. Today, on-going professional development of teachers has risen significantly on the political agenda, evidenced by the setting up of the national network of science centres.

However, despite the achievements of the past fifty years, there is a sense that all is not well with school science teaching. School science teaching laboratories and equipment seem increasingly remote from the world of twenty-first century science and there is renewed concern about the level and adequacy of technical support. While most science teachers have welcomed the principle of a national curriculum, some have found teaching it a demoralising experience that undermines their professional expertise, diminishes pupils' enjoyment of science at the secondary level, and narrows the range of laboratory work undertaken. Questionable notions of generalisable 'good' or 'evidence-based' practice have led to increasingly detailed advice to science teachers on how they should conduct their work, hinting at the emergence of a 'national pedagogy'. The introduction of double-award science has not led to increased numbers of pupils studying science beyond the age of 16; nor has it mitigated the long-standing unpopularity among girls of physics as an A-level subject. The expanding science departments within universities in the 1960s have given way to departmental closures or mergers, and a long-term solution to the shortage of well-qualified teachers, especially of physics and chemistry, remains elusive.

It seems clear that while many pupils are interested in science, they are much less interested in a *school* science education which gives little or no attention to the science-related issues that they encounter in their daily lives. This has led to significant curriculum initiatives such as *21st Century Science* and the attempt to radically reform the secondary science curriculum in Northern Ireland. In England and Wales, more long-term and fundamental change in both curriculum and assessment is promised by the Tomlinson report into the education of pupils between the ages of 14 and 19.

At present, most of the day-to-day work of science teachers remains that of teaching groups of 15–30 young people in classrooms or laboratories. Despite the changes referred to above, contemporary science lessons have obvious affinities with the ways in which science was taught in secondary schools a century or so ago. How long this will remain the case, and how aims, content, teaching methods and assessment strategies will change, are questions for the future. Fortunately, it is not the task of the historian to answer them.

Further reading

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