**The schooling of the sciences**

Although much research is still needed, the schooling of the sciences has received more attention than most other subjects of the curriculum. Both historical and ethnographic studies indicate the socially and politically constructed nature of school science curricula and, more particularly, the ways in which both content and pedagogy reflect several widely held assumptions about, for example, pupils’ ability, their likely future occupations, the role of women in society and, ultimately, about the purpose of particular types of curriculum or schooling.

The attention given to school science reflects the fact that aspects of the sciences, such as laboratory work, present unique problems. It is also an acknowledgement that accommodating the scientific disciplines in the curriculum challenged the historical basis of school education. That basis lay in the teaching of the classics and mathematics, subjects whose status as the foundation of a liberal education was legitimised and defended by the universities. In most education systems, the challenge emerged with particular force in the nineteenth century and was directed primarily at those schools such as grammar schools and gymnasia that enjoyed a close historic link with higher education.

The curriculum histories of chemistry, physics and biology in these schools are different, largely as a result of differences between these subjects and their relative maturity when science was first schooled in the mid-nineteenth century. Despite the scientific revolution of the seventeenth century, physics was professionalized later than chemistry and, in many respects, it can be regarded as a subject constructed from a range of intellectually and socially diverse fields (heat, light and sound, magnetism and electricity, mechanics and properties of matter) for the purposes of education. In contrast, inorganic and organic chemistry, with a common focus on understanding the preparation, properties and analysis of materials, offered a more straightforward resource for curriculum construction: physical chemistry was not to gain a place in school curricula until the twentieth century. The timing of the introduction of chemistry into schools also reflected its contemporary salience as a discipline: if the case for teaching science in schools had succeeded in England a generation earlier, it may well have favoured geology rather than chemistry. Although biology had long been institutionalised as zoology and botany, the universities offered no ‘model’ upon which a school biology curriculum might be based. In addition, as a school subject, zoology, with its emphasis on anatomy and physiology, was widely judged appropriate only for future medical students, while simultaneously raising concerns about exposing young women to the more intimate aspects of the discipline. The study of systematic and economic botany, along with plant morphology and natural history, represented altogether safer educational territory. However, both botany and zoology were also open to the charge that neither provided an opportunity for experimental work in a teaching laboratory, perceived as an essential condition for accommodation within school curricula. It was not until the mid-twentieth century that satisfactory schemes of work involving observation and experiment and based firmly on general biological principles could be developed. Biology as a discipline therefore secured a place in most school curricula much later than either chemistry or physics.

Unsurprisingly, school science curricula in grammar schools and gymnasia became something of a pre-professional training, supported by a pedagogy similar to that used to teach undergraduates. School chemistry emphasised the preparation, properties and uses of the elements and their compounds, together with qualitative and quantitative analysis. Physics stressed the importance of precise measurement, an understanding of the basic laws governing, for example, motion, electrical conductivity and the transfer of heat, light and sound, along with an ability to solve what quickly became a standardised set of associated calculations. Differences in the science curricula of these schools in different education systems were marginal, rather than fundamental, often reflecting country-specific manufacturing processes or national claims about the priority of scientific discovery.

Where the historic link between schools and universities did not exist, as in the case of the large numbers of schools created to provide public elementary education, the challenge of accommodating the sciences in the curriculum was different and the schooling of the sciences followed a different path. The scientific disciplines were raided or adapted to construct curricula designed to meet different future social roles and employment needs. Titles such as ‘How electricity is made and distributed’, ‘The science of common things’, ‘The chemistry of everyday life’ and ’Science in the Home’, ‘Human Biology’ and ‘Social Biology’ are representative of many initiatives of this kind. In some education systems, broader courses with titles such as ‘Science’ or ‘General Science’ were developed but, despite some success, these ultimately failed to overcome the conceptual, linguistic, methodological and philosophical differences between the contributing scientific disciplines and they fell out of favour as a demand arose for a greatly increased number of qualified scientific personnel. The challenge for pedagogy, too, was different. Laboratory-based work designed to introduce pupils to the grammar, syntax and methods of science was replaced by practical activities more directly related to employment, to anticipated social roles and, in some instances, to wider social and political concerns such as health, diet and child-rearing.

Pedagogy in all types of schools has also been subject to more specific educational influences, notably assumptions about how children learn and should be taught. In many Anglophone countries, the criteria used to determine the order in which topics should be taught was initially determined by the conceptual difficulty that each was presumed to present to students. Thus a course in elementary physical measurements would be followed by the study of heat, light, sound and mechanics, followed by, or alongside, elementary chemistry. Although this criterion gave way to others, for example, the notion that the interest of children in science exhibited a rhythm corresponding to the rhythm of its history, it was not until the mid- twentieth century that research-based insights into children’s learning and understanding of scientific concepts came to play a significant role in determining pedagogy.

In other systems, notably in continental Europe, where educational theorising was differently conceptualised, the notion of ‘didactic’ was of central importance in the schooling of science. The underpinning notion of didactic is the belief that it is possible to construct a scientific discipline (didactic) by drawing upon a range of other disciplines relevant to the processes of teaching and learning. The difference between these continental and Anglophone traditions remains important and it is not merely semantic: it reflects contrasting views of what constitutes ‘scientific research’ in education and thus of the role that disciplines such as philosophy, psychology and sociology can and should play in curriculum construction and pedagogy.

The latter half of the twentieth century was characterised by profound changes in science, in society and in their interactions and, in some education systems, by major changes in the structure of schooling. A growing post-war demand for qualified scientific personnel, prompted in part by the Cold War, prompted a global movement for school science reform. In the twenty five years or so that followed the end of World War II, the scientific content of school curricula was modernised, new assessment techniques developed and pupils encouraged to learn by engaging in ‘hands-on’ laboratory activities. In some cases, notably at the primary level of schooling, the reform drew upon Piagetian ideas about young people’s understanding of fundamental scientific concepts such as mass and time, ideas that eventually led to the development of a substantial field of constructivist research. At the same time, the abolition of selective systems of schooling raised challenging questions about the educational function of school science and highlighted the problem of accommodating the different approaches to science teaching referred to above within a common secondary school.

By the 1970s, a number of other factors had begun to shape the schooling of science. These included the rise of environmental concerns, increased attention to long-standing gender and other equity issues and the challenge presented by post-modern perspectives on science itself. In addition, there was anxiety, notably in the developed world, about a decline in the popularity of the physical sciences as subjects of advanced study and a recognition of the need for a curriculum response to the growing number of complex ethical and political problems posed by scientific and technological developments. That response took the form of an international science-technology-society (STS) movement. Impelled by a mixture of motives and manifest in diverse curricula, the movement eventually owed less to the community of professional scientists within higher education than to initiatives by science teachers and researchers. Examples include the Science for Public Understanding Programme in the USA and the Science and Society Project in the UK. Many of these initiatives made use of the growing power of information and communication technologies, especially the Internet which has become an increasingly important factor influencing how science is taught and learnt.

As the numbers of young people wishing to study science continued to decline in the closing decades of the twentieth century, doubts were raised about the merits of earlier curriculum initiatives as well as the mechanisms used to promote reform. When these doubts were reinforced by the disappointing results of surveys of the level of public understanding of science, attention inevitably focused on the issue of standards of achievement. This later acquired added political and educational salience as a result of international comparative studies such as PISA and TIMSS, the outcomes of which led directly to changes the school curricula of several countries. The challenge facing all education systems, therefore, was how best to promote the higher and more general scientific literacy deemed necessary for a variety of economic, political, social and personal reasons. In some systems, government responded to the challenge by taking direct control of the science curriculum and its assessment, specifying intended and measurable learning outcomes and offering suggestions for best pedagogical practice. Where central government control of schooling was not possible, as in the USA, it was necessary to respond in ways that accommodated the delocalised nature of curriculum control.

As governments have demanded greater accountability of investment in schooling, they have inevitably gained greater influence over what and how school science is taught and assessed. This has created an educational bureaucracy that, in many countries, has overturned the historic roles accorded to academia and science teachers to determine the form, content and pedagogy of school science. The longer term consequences of this shift in authority remain to be determined.

REFERENCES

Apple, M. (1979) Ideology and the Curriculum. Routledge and Kegan Paul, London.

Goodson, I.F., Ball, S.J. (eds.) (1984) Defining the Curriculum: Histories and Ethnographies. Falmer Press, London.

Layton, D. (1973) Science for the People: The origins of the school science curriculum in England. Allen and Unwin, London.

Rudolph, J.L. (2002) Scientists in the Classroom: The cold war reconstruction of American Science Education. Palgrave, New York.

Solomon, J., Aikenhead, G. (eds.) (1994) STS Education: International Perspectives on Reform. Teachers College Press, New York.