Book Section:
Jenkins, EW (2014) E.J.Holmyard and the historical approach to science teaching. In: International Handbook of Research in History, Philosophy and Science Teaching. Springer Netherlands , 2283 - 2408. ISBN 978-94-007-7653-1

https://doi.org/10.1007/978-94-007-7654-8

E. J. Holmyard (1891-1959) and the historical approach to science teaching

E.J.Holmyard (1891-1959) and the historical approach to science teaching

Edgar W. Jenkins

Centre for Studies in Science and Mathematics Education, University of Leeds, Leeds, UK.

e.w.jenkins@education.leeds.ac.uk

Abstract: E. J. Holmyard was a distinguished scholar and schoolmaster in England in the first half of the twentieth century. After graduating from Cambridge in both natural science and history, he quickly established a reputation for his research into the early history of chemistry, especially Islamic alchemy, and for his advocacy of a historical approach to the teaching of science. Both these interests found expression in his large number of school chemistry textbooks, many of which were highly successful and innovative publications, placing chemistry in its wider historical and cultural contexts and offering insights into what today would be called 'the nature of science'. This essay explores the historical method of science teaching with particular reference to Holmyard's ideas and his authorship of textbooks, and comments upon why the history of science has featured so prominently in the history of school science education.

Introduction

Eric John Holmyard[1] was a scholar and schoolmaster and a significant figure in the history of science and in science education during the first half of the twentieth century. Although his research into alchemy is well-known to historians of science interested in early chemistry, his historical approach to science teaching has received much less attention from the science education community, the study by Kinsman (1985) being a conspicuous but unpublished exception.

Born in 1891 in Midsomer Norton, Somerset, in the West of England, his father, Isaac Berrow Holmyard, was a schoolteacher in a national school, i.e., an elementary school set up by The National Society for Promoting the Education of the Poor in the Principles of the Established Church. After attending Sexey's School in Bruton, Holmyard went up to Sidney Sussex College, Cambridge, to read history and science. He graduated in both these disciplines with a first in natural science and a second in part two of the history Tripos. After working as a Board of Agriculture Research Fellow at Rothamsted Experimental Station, he

[1] Although Holmyard used both his initials in all his publications, he preferred the name John to Eric (McKie 1960).

taught briefly at Bristol Grammar school and Marlborough College before becoming head of science [2] at Clifton College in Bristol in 1919.

Holmyard entered the teaching profession at a time when schooling in England was undergoing a period of significant change. The Education Act of 1902 had created Local Education Authorities (LEAs) with responsibility for publicly-funded elementary and secondary schools, with a small proportion of pupils from the former selected to enter the latter on the basis of an examination at the age of 11. Secondary, i.e., grammar, schools under the control of the LEAs were quickly established across the country and many chose to organise themselves on the basis commonly associated with the public (i.e., private) schools, creating houses, appointing prefects and promoting competitive sporting activities. However, unlike the public schools, the curriculum of the LEA grammar schools was governed by Regulations issued annually by the Board of Education which required the teaching of both practical and theoretical science. Despite the experience of pioneering schools like Clifton College, much remained to be learnt about best to organise and teach science in the grant-aided secondary schools, 1,027 of which were established by 1914 (Simon 1974, p.363). There was therefore much debate about the order and manner in which topics should be presented and taught and about the roles to be accorded to expository teaching, teacher demonstration and laboratory work conducted by pupils (Fowles 1937; Jenkins 1979). For reasons that are discussed below, that debate became particularly significant in the years following the end of the First World War.

This essay reviews Holmyard's contribution to the historical method of science teaching and comments upon why the history of science has featured so prominently in the history of school science education.

The Historical Method of Teaching

Founded in 1862 under the headmastership of John Percival, Bishop of Hereford, Clifton College was somewhat unusual among the 'public' schools in England in the mid-nineteenth century in that it 'took science seriously' (Brock 1996, p.373). It was a legacy upon which Holmyard was able to build. Under his leadership, the College acquired an astonishing collection of manuscripts and first editions of scientific works for its new library[3] and established an outstanding reputation for its science teaching. According to the author of the

[2] The terms of Holmyard's appointment were unusual in that he was relieved of all out-of-school duties and, until 1936, lived in Clevedon and travelled daily to Clifton (Kinsman, 1985; Williams, 2002). His appointment at Rothamsted reflected his study of biology in Part 1 of the Tripos examination

[3] The Library, known as the Stone Library, was built with funds from Old Cliftonians. The first editions purchased for the library included Newton's *Opticks* and Darwin's *On the Origin of Species.* Clifton College also purchased material at Sotheby's 1936 sale of Newtoniana. Opened in 1927, Holmyard was justifiably proud of the new Science Library which he believed had 'no rival in any school in the world' (Holmyard, writing in the *Cliftonian* of June 1927 and quoted in Williams 2002, p.204).

relevant entry in the *Dictionary of National Biography*, 'Under his guidance, Clifton established a reputation for science probably unequalled, and certainly not surpassed, by any other British school' (Williams 2002; see also Williams 2004).

Holmyard was an enthusiastic advocate of a historical approach to the teaching of chemistry which helped pupils to learn how discoveries were made and, more particularly, to familiarise themselves with the ideas in the minds of the researchers, and to understand the methods by which they had overcome difficulties. His advocacy reflected a deep scholarly interest in the early history of chemistry, notably in alchemy, at a time when the history of science was becoming established as a distinct academic discipline: the journal *ISIS*, for example, was founded by George Sarton in 1912 and Department for the History and Methods of Science Department at University College London in 1921. Holmyard taught himself Arabic and acquired a good working knowledge of Hebrew, skills which enabled him to edit several important Islamic alchemical texts and to shed light on the work of early alchemists, research for which the University of Bristol awarded him a D. Litt. in 1928. He was in demand as a reviewer for several journals, including *The Journal of the Royal Asiatic Society*, reviewing publications in French and German as well as English. He served (1947-50) as a Vice-President of the newly-formed British Society for the History of Science and later as an Ordinary Member of its Council (1953-4) and as chairman of the Society for the Study of Alchemy and Early Chemistry. He was also a corresponding member of L'Académie Internationale de l'Histoire des Sciences.

In a detailed review of approaches that had been recommended or used to teach chemistry, the schoolmaster George Fowles[4] suggested that a historical approach could be biographical, recapitulatory or be based upon the evolution of scientific ideas (Fowles 1937, pp.511-18). The first of these relied on the biographies or published diaries of famous scientists and was sometimes coupled with the anecdotal in an attempt to relate the research of individual scientists to wider social, economic or political concerns. The work of Haber on nitrogen fixation is an obvious example. The recapitulatory approach was adopted by Perkin & Lean in their *Introduction to the Study of Chemistry*, first published in 1896 (Perkin and Lean 1896).[5] Convinced that 'the order in which problems have presented themselves to successive generations is the order in which they may be most naturally presented to the individual', they claimed that many of the chapters had been worked through by elementary students in the laboratories of Owens College, later the University of Manchester (Perkin and Lean *op.cit*., pp.vii-viii and xi). However, the recapitulatory approach does not seem to have been widely used, partly because it involved devoting time to teaching ideas and processes

[4] For Fowles, see Jenkins, 2000. Fowles was a close friend for over thirty years of John Bradley who regarded him as his 'friend and mentor' and his book as 'indispensable to the teacher of chemistry' (Bradley 1988, p.2).

[5] Perkin and Lean's book held 'a position of honour' on the bookshelves of John Bradley who was introduced to it by his teacher at Archbishop Holgate's Grammar School in York, Henry Worth (1870-1949). Bradley was a distinguished teacher and teacher educator who was much influenced by the writings of Mach and who taught at Christ's Hospital where he met H.E.Armstrong. (Bradley *op.cit.*).

that had long been superseded or could be taught much more effectively and economically in other ways. Fowles, writing a generation later, suggested (*op.cit.,* p.515) that the approach could work well only when controversy and blind alleys did not significantly interrupt the presentation of the historical narrative. His overall judgement (*op.cit.*, p.514) was that the 'much vaunted' recapitulatory method had 'never been faithfully carried out in practice'.

The evolutionary approach was intended to help students understand the personal, intellectual, professional, economic and social factors that characterised the historical path towards the current understanding of natural phenomena. The value of this approach lay in countering the view that former ideas were simply the absurd outcomes of prejudice or mistaken judgement and in understanding the qualified degree of confidence that should be placed in more contemporary explanations of natural phenomena.

> We like to be thought devotees of truth uninfluenced by prejudice, as open-minded and serene students of nature, free from suppositions and welcoming every fact that comes within our ken… When the errors of our predecessors are forced upon our notice we may lament them or be amused or may seek to excuse them, but that the same lamentations and excuses may some day have to be made for us we can hardly think possible (Lodge 1925, p.i).

Although he never referred to it as such, it is this evolutionary approach that most aptly describes Holmyard's historical method of teaching chemistry. He argued his case at a vacation course for science teachers held in Oxford in the summer of 1924[6] and in an article published in the same year in *The School Science Review*, the journal of the Science Masters' Association, an organisation of which he was a committee member and, a year later, President (Holmyard 1924a, pp.227-33).

He began by addressing the widely held belief that school chemistry could be taught in two ways, depending upon whether the students would eventually become chemists or not. For the former group, the emphasis was placed on the grammar and syntax of the discipline, on learning the rudiments of canonical chemistry. For the latter, the 'chemistry of everyday life' was usually accorded priority. For Holmyard, this distinction was 'a grave fallacy' that rested upon 'the fundamental misconception that chemistry is a craft, when essentially it is a philosophy' (*ibid.,* p.227). He was thus scornful of the enduring educational merits of snippets of chemical knowledge that enabled someone later in life to solve an acrostic in a daily newspaper or to understand that 'the 'will o'-the-wisp' is caused by the combustion of marsh gas...produced by the action of little insects, called germs (*sic*), upon dead plants' (p.228). He does not, however, suggest that knowledge of this kind is to be regarded as having no value. On the contrary,

> ...how often, after having cut myself while shaving, have I thanked Heaven that my chemical education had been carried to such a degree of perfection that I knew a trivalent cation was especially effective in the coagulation of colloids!

[6] Holmyard's contribution to the course was subsequently published as a pamphlet entitled *The Teaching of Science* (Holmyard 1924b).

He then adds, in a remarkable sentence, that

> Merely to have rubbed on alum in an unintelligent way would have robbed the operation of all its ecstasy, and I should not have felt that piquant sense of superiority over my daily companion in the train, Lucas, the stock-broker, who is so ignorant that he doesn't even know the empirical formula for the starch in his own collars! (p.229).

This is one of several examples in Holmyard's article of what he called 'levity', the intended irony of which could all too easily be misunderstood. However, all the examples served to introduce his main argument, namely that the chief value of chemical education stemmed from the precise, logical and formal character of the discipline, not from its personal or economic utility. He then went on to address the question why chemistry has an educational advantage over other disciplines, such as mathematics, which can be characterised in similar terms. His answer was that chemistry appeals both to intellect and to emotion and is not a 'cold, discarnate scheme of mental gymnastics' (p.231).

Claiming that 'the immediate [favourable] reaction to biographical details is a universally recognized trait of youthful psychology', Holmyard asked who 'could fail to be stirred by accounts of Pasteur's romantic search for *l*-tartaric acid, of Priestley's discovery of oxygen, of Moissan's isolation of fluorine?' He claimed that he had successfully used his historical approach with his own students at Clifton.

> Personally, I have never found any difficulty in getting a boy to 'believe' in the 'truth' of the sulphur-mercury theory of metals, to get him to abandon it for phlogiston theory, or to abandon this in turn for the oxygen theory, with the result that the last theory is regarded by him in a very different way from that in which a boy looks at it who has had it taught to him dogmatically (Holmyard 1924a, p.232).

In addition to arguing for, and illustrating, Holmyard's historical approach to teaching chemistry, his article in *The School Science Review* also provides some insight into his understanding of the philosophy of chemistry. It is clear that, for Holmyard, this understanding did more than support his historical approach to chemical education: it provided its underpinning rationale. Only by adopting such an approach could students be led to understand that 'Science in general and chemistry in particular are but conceptual schemes which must always bear an unknown relation to the precepts they correlate' (p.231). Elsewhere, he invokes a biological analogy to express his view of the history of science.

> '…the theory of evolution is applicable to the development of science no less than to the world of birds, beasts and flowers (Holmyard 1925c, preface).

For Holmyard, scientific knowledge is to be regarded as essentially pragmatic, not connected with questions about the nature of reality, and as free of any special ontological assumptions and untainted by narrow questions of economic benefit. For the anonymous reviewer of his pamphlet, *The Teaching of Science*,

> Mr Holmyard is not concerned with a universe of absolute truth and rigid law, but with a humble and tentative hold on the precarious hypothesis of an external world (SSR 1925a, p.266).[7]

Almost twenty years later, Holmyard wrote that

> Reality, if it is to be discussed at all, must for the present be discussed as a philosophical problem, and the scientist as a scientist need not adventure into such regions…a theory is merely a conceptual model of perceptual facts...a tool rather than a creed (Holmyard 1944, p.126).

Holmyard's concern to put some distance between the discipline of chemistry and its uses brought him into conflict with his fellow members of the Science Masters' Association (Layton 1984, p. 203).

> …any scheme that sets out to be utilitarian, in the narrow sense of the word, or merely 'interesting' is blatantly immoral, and rightly deserves the censure it invites (Holmyard 1924a, p.230).

He therefore had no time for the courses of 'General Science' which the Association was strongly promoting in the interests of 'science for all'.

> I am…with those who cry 'Science for All' but I would add 'and Dabbling Science for Nobody'. I have no sympathy with kindergarten schemes of 'general science'. [They are] fallacious and shallow…(Holmyard 1924a, p.229).

If students of science are to be helped towards what Holmyard described as the 'truth', only the historical method of teaching could bring this about.

> The historical method is not, I believe, one of several equally good alternative schemes of teaching chemistry in schools: it is the only method which will effectively produce all the results at which it is at once our privilege and duty to aim (*ibid.*).

In addition, it was only the historical method that could enable students to appreciate to the full 'the serene joys of the intellectual life' and steer school science education in a much needed new direction.

> …the main result of the teaching of science in our schools has been to accelerate the spread of that contempt for and indifference to ethical, moral and aesthetic values, and to spiritual and religious truth…perhaps the chief characteristic of our civilisation (Holmyard 1925b, p.490).

Nothing less than a fully worked out historical approach could bring this about and he cautioned that

> Many teachers, in all good faith, imagine that they are adopting this method [of teaching] if they drag in a few biographical details…fascinating as it may be, and valuable as it certainly is, in stimulating the child's interest and attention, it does not by itself constitute the historical method (*ibid.,* p.492).

[7] Unless otherwise indicated, all reviewers were anonymous.

Holmyard's views were supported by J. W. Mellor, FRS, author of several textbooks and of a landmark multi-volume *Comprehensive Treatise on Inorganic and Theoretical Chemistry.* Asserting that 'every teacher now recognises that it is a sheer waste of time to introduce many abstract ideas into an elementary science course without a previous survey of the facts from which the generalizations can be derived', Mellor[8] argued that 'in most cases the historical mode of treatment is correct, because the generalizations have usually developed from contemplation of the facts' (Mellor 1932, preface).

Criticism of the Historical Approach

Holmyard will have been well aware that the historical approach to teaching science also had its critics. The pioneering Cambridge chemist, Ida Freund, author of a seminal book, *The Study of Chemical Composition* (Freund 1904), had little time for such an approach. She fully understood the importance of understanding the history of a scientific discipline and had written a prize-winning historical study of the constitution of matter, some of which almost certainly influenced the approach taken in her 1904 book. Nonetheless, to those who wanted students to retrace the paths by which scientific discoveries had been made, she replied that

> Even if such a plan could be consistently adhered to …it is better to take the shorter way to the goal, this being after all a way by which the discovery might have been made (Freund 1904, quoted in Fowles, *op.cit.*¸ p.513).

In 1929, in a book entitled *Science Teaching: What it was – What It Is - What it Might Be*, F.W.Westaway[9] warned that

> if the historical method is to be adopted, the general method of the history teacher must be followed…What is the point of discussing Roger Bacon and his work unless a boy first understands something of the spirit of mediaevalism – any person who attempted to unravel nature's secrets must be an emissary of Satan himself, and punished accordingly (Westaway 1929, p.32).

For Westaway, this condition meant that 'teaching in accordance with historical sequence' could not 'be recommended for subjects usually taught up to the fifth form [i.e. about the age of 16] –physics, chemistry and biology' (*idem.*). He was cautious of the slow progress that the historical method allowed, advising that 'it simply does not pay to spend a whole lesson over, say, the phlogiston hypothesis'. Even so, he felt that some aspects of

[8] Joseph William Mellor CBE, FRS (1869-1938) was born in Lindley, a suburb of Huddersfield in the West Riding of Yorkshire but left for New Zealand at the age of 10. He returned to England in 1899 to take up an appointment as chemist to the Pottery Manufacturers Federation in Newcastle-under Lyme. Mellor soon established himself as a researcher of international standing, working on the structure and properties of ceramic materials. In 1934, he was appointed Director of the new laboratories of the British Refractories Research Association, named in his honour. In addition to his monumental multi-volume treatise on inorganic chemistry, he was a highly competent mathematician and his book on mathematics for chemists and physicists became widely used (Mellor 1902).

[9] For Westaway, see Jenkins 2001 and Brock and Jenkins in this volume.

school science, such as astronomy, were well suited to being 'developed historically and to great advantage' (*ibid.* p.31).

In 1930, the historical method, and Holmyard in particular, were the subject of criticism by H.H.Cawthorne. A graduate of King's College, London, Cawthorne had worked in teacher education at the University College of the South West, Exeter, before taking up a post at Firth Park secondary school in Sheffield. In his *Science in Education* (Cawthorne 1930), he devoted a whole chapter (pp.66-75) to the historical method which he is careful to distinguish from a more narrowly biographical approach to school science teaching. While acknowledging that the historical method of teaching has merits, including preventing a 'dogmatic treatment of present-day thought', Cawthorne challenged the notion that the standpoints of the student and of the scientific discoverer are roughly the same. He concluded that it was not necessary for students to 'wade through all the mire and clay of controversy' which have, at times, been obstacles to the progress of science. His advice to teachers was that in order to prevent confusing students or using excessive time, it was necessary to 'short-circuit' some parts of the full historical argument. As a further obstacle to teaching in the way advocated by Holmyard, he reminded his readers that the mind of the mid-twentieth century student was packed with 'many odd scraps of information which the most fertile imagination of the seventeenth century philosopher could never have supplied'. He offered the example of liquid air, a concept familiar to many of his students but which would have nonplussed the early members of The Royal Society (*ibid.,*p.75). Today, when scientific ideas and explanations are widely available in museums and the print and broadcast media, Cawthorne's point is even more telling.

For another schoolmaster, Fowles, writing in 1937, while the historical method of teaching chemistry was 'attractive in theory' and 'appealed to the philosophically minded…few had drawn up a scheme or work or attempted to put the method in practice' (Fowles *op.cit.*, p.513). He wondered whether students, helped by their teacher to understand that a theory was no longer tenable, might be puzzled why it was retained in the face of new experimental evidence by 'men of the depth of intellect of Priestley and Cavendish'. He asked who, 'Notwithstanding the simplicity of the experiments …decomposes mercuric oxide with the heat of the sun concentrated by means of a 12-inch lens…when oxygen is much more easily prepared by other means?' (*op.cit.*, p.514). His judgement on the historical method was that 'one is constrained to believe that the students have done little more than accept the belief of the teacher' (p.517).

However, there was more to Holmyard's advocacy of the historical approach to science education than the insights it could offer into what today is referred to as 'The Nature of Science'. It also added a much-needed human dimension to the subject.

> If Science is to retain the honourable place it has won in the educational system of this country…we shall have to recognise that it is the greatest of the "humanities", and deliberately abandon the so called "utilitarian" standpoint (Holmyard 1922, preface).

It is interesting to place Homyard's rejection of the 'utilitarian standpoint' alongside the view of Harold Hartley, FRS,[10] a distinguished physical chemist and contemporary who saw science,

> …not merely as an academic subject- nor only as a basis for applied technological development but as a great cultural adventure that comprised both of these: as an historical sequence, having its nourishing roots in the past and its growing branches thrusting constantly into the future (Ogston 1973, p.366).

Holmyard was by no means without support in seeking to present science as a humanity. Turner, in her account of the history of science teaching in England, came to the conclusion that

> …if science teaching is to mean anything more than the acquisition of a few tags of knowledge and a certain skill in manipulation we must accord it a place among the humanities…The human side is perhaps best introduced by a carefully selected historical treatment (Turner 1927, p.191).

In the aftermath of the First World War in which chemistry had played such a massive and destructive role, recasting science as a humane study was widely regarded as necessary and it helps to explain why, despite the practical difficulties of implementing Holmyard's ideas, the incorporation of at least some elements of the history of science in school curricula received a broadly sympathetic hearing.

> How necessary Science is in War…we have learnt at a great price. How it contributes to the prosperity of industries and trade, all are ready to admit. How valuable it may be in training the judgement, stirring the imagination and in cultivating a spirit of reverence, few have yet accepted in full faith (Natural Science in Education 1918, para.4).

Reaction to the role of science in the First World War was not the only influence at work in seeking to 'humanise' school science. During the 'battle of the books' that had broken out in the middle of the First World War, supporters of a classical education had reacted vigorously to the claims of a self-styled 'Neglect of Science Committee' established to promote science education and research (Jenkins 1979). Ramsay MacDonald told the House of Commons that this Committee was 'practically telling us to clear the humanities out of our schools' (Hansard 1916, col.906) and an editorial in *Blackwood's Magazine* in 1916 described the 'ferocious attack on the humanities as evidence of the 'unbalanced men of science who wish to kill off all learning other than their own'. Those who had praised

[10] Sir Harold Brewer Hartley, C.H., FRS, was taught chemistry by H.B.Baker at Dulwich College in London who encouraged him to read and buy old chemistry books. Hartley went on to Balliol College, Oxford and to develop a life-long interest in the history of the discipline. During his long life he held a variety of academic, business and industrial appointments. He secured the Lewis Evans collection of scientific instruments for the University of Oxford and was a frequent contributor of historical articles, especially about 19th century English chemists, to the *Notes and Records of the Royal Society* of which he was the editor for eighteen years. The preface to his *Studies in the History of Chemistry* (Hartley 1971) reveals that the book was commissioned nearly 70 years earlier!

German scientific and technological achievements before the war now found their own evidence being used against them.

The clash between the scientific and classical contributions to education was not confined to the United Kingdom and the battle was not always conducted in terms conducive to effecting a rapprochement. In the USA, for example, one commentator opined that 'Largely without the benefit of the Classics, it is not to be expected that [the ordinary scientist] should know what the Humanists are saying or realize his faults' (Glaser 1924, p.30). In the United Kingdom, the distinguished Wykehamist classical scholar and educator, Sir Richard Livingstone, claimed in his *Defence of a Classical Education* that the fundamental weakness in science as a vehicle of a liberal education was that

> …[science] hardly tells us anything about man. The man who is our friend, enemy, kinsman, partner, colleague, with whom we live and [have our] business, who governs or is governed by us [never once] comes within our view (Livingstone 1916, pp.30-31).

It is clear that Holmyard, who regarded science as an integral part of culture, would have rejected Livingtone's claim that science 'hardly tells us anything about man'. It is equally clear, as noted above, that Holmyard thought science as it had been taught had accelerated a contempt for, and an indifference to, ethical, moral and aesthetic values and to spiritual and religious truth. It is noteworthy therefore that the Foreword to his *Inorganic Chemistry*, first published in 1922, was written, presumably at Holmyard's invitation, by a leading classical scholar, Cyril Norwood. Holmyard would have encountered Norwood when the latter served as headmaster at Bristol Grammar School (1906-16) and Marlborough College (1917-25) respectively, before moving on to the headship of Harrow (1926-34). Norwood has been described as the 'quintessential insider of English education in the first half of the twentieth century' (McCulloch 2006, p.55; see also McCulloch 1991). He was an influential source of government advice, eventually being knighted for his services to education. In 1929, Norwood published *The English Tradition of Education* which offered a deeply complacent and conservative view of the past, a past that was closely linked to the teaching of the classics in the English public and endowed grammar schools. In his Foreword to Holmyard's book, Norwood is deeply critical of the system of Higher Grade Schools that had developed in England during the last quarter of the nineteenth century (Vlaeminke 2000). Funded for the most part by grants from the Department of Science and Art, these locally controlled post-elementary schools attached much greater importance to science than many public and endowed grammar schools and provided an 'alternative' secondary education in all but name.[11] Norwood claimed that the teaching in these schools had been 'one-sided' and

---

[11] See McCulloch (1984). The Higher Grade Schools are seen by some historians as constituting an 'alternative road' to that represented by the traditional grammar school curriculum. They were swept away by a series of legislative changes between 1899 and 1902, although some re-emerged as secondary i.e., grammar, schools under the control of newly created Local Education Authorities. See Vlaeminke (2000).

excessively formal and that it had taken the Great War to forcibly remind the nation that things were not well. He saw Holmyard's *Inorganic Chemistry* as offering a way forward.

> [The author] knows how to teach with breadth and without exclusiveness. Its pages give information and provoke curiosity: at many points they suggest that there are other realms of knowledge of a quite different sort (Norwood 1921, p.*v*).

It was an endorsement that one can safely assume met with Holmyard's approval.

When the newly-formed Science Masters' Association held its Annual Meeting in 1920, there was widespread agreement that school science courses needed to be both broadened and 'humanized', although there was much less confidence about how this could be achieved. For some, the way forward lay with a broad course of General Science which 'furnished the mind' and 'gave some knowledge of the world in which we live' (Tilden 1919, p.12). For others, it was essential to capture the spirit and romance of scientific endeavour by incorporating a biographical element into school science education, 'the history of men and the setting forth of noble objects of action' (Sadler 1909, p. *xi*). For yet others, it was Holmyard's evolutionary approach to the history of scientific ideas, or at least some aspects of it, that seemed to have most to commend it.

Unsurprisingly, each of these possible directions for science education reform presented difficulties. Despite the success that Holmyard claimed he had achieved with his own students, his historical method was the subject of on-going debate and critical commentary throughout the inter-war years. Interestingly, there appears to be no evidence that he sought to reply to his critics by, for example, writing for *The School Science Review* or publishing a more detailed and practical account of his historical method to which science teachers could refer.[12] Fowles (*op.cit.*, *p.*517) expressed some admiration for Holmyard's success in 'getting a young class to grasp the doctrine of phlogiston' but questioned 'how little of elementary chemistry' could be taught along the lines advocated by Holmyard and how far it was expedient, and actually possible in the time usually available, to secure topical development along such lines. Although it is impossible to be sure how widely Holmyard's

---

[12] A comparison with H. E. Armstrong is of some interest. Both men sought to give students an insight into how scientific knowledge was obtained and validated, although Armstrong's emphasis on the practical teaching of 'scientific method' could not be more different from Holmyard's more complex, nuanced historical approach. Unlike Holmyard, Armstrong was a vigorous promoter of his *virus heuristicum Armstrongii* and even compiled a book setting out his ideas (Armstrong 1903), although its lack of coherence made this a less useful advocate of his cause than it might have been. See, for example, Browne 1954/1966 and Brock 1973. For both heurism and the historical method of science teaching, science teachers were undoubtedly the weakest point. As individuals, Holmyard was described as a 'quiet' and 'tolerant' man (McKie 1960, p.5), as having 'a modest and retiring disposition' (The Times, October 15th 1959) and an 'imperturbability of temper' (Singer 1959, p.17), descriptions that could never be applied to the hot tempered Armstrong who 'always made one think [but] was fond of saying that very few…were capable of doing so' (Hartley, 1971, p.195). For Holmyard's views on heurism, see Holmyard 1925b, p.490).

approach to school science was adopted, it seems clear that for most science teachers it presented formidable, even insuperable, difficulties. Few teachers could command the knowledge of the history of chemistry or physics required to take students back and immerse them in the period under consideration and there is little evidence to suggest that the obstacles identified by Cawthorne, Fowles and others were successfully overcome. In a book written 'for teachers and training college students', John Brown, a school inspector for the London County Council, could do no more than advise that 'with older pupils, the study of a certain amount of *historical development'* of the subject will prove profitable (Brown 1925, pp.45-6).

'Ships' surgeons are always truthful!'

While Holmyard's historical method may have failed to find widespread favour among his science teaching colleagues, his scholarly achievements in the history of science were able to find generous expression in his large number of school science textbooks. There are likely to be few, if any, chemistry teachers of an older generation familiar with the English education system who will not be able to recall his name. Some may even be familiar with above quotation - of which more below.

Holmyard was a prolific author. Throughout the interwar years in particular, publications concerning the history of science appeared alongside a steady stream of school science textbooks. The British Library Integrated Catalogue lists over a hundred entries for Holmyard (although this number includes several different editions or reprints of the same book) and a large proportion of the entries relates to works published between 1922 and 1939. The 1920s alone produced *Chemistry to the Time of Dalton,* published in 1925 (Holmyard 1925), two translations of Avicenna (1927) and a critical and important translation of the Arabic works of Jâbir Ibn Hayyân (Holmyard 1928), a year that also saw the publication of *The Great Chemists*. The same decade also witnessed the first publication of over a dozen school science textbooks, some of which were reprinted or revised and remained in use for at least the next thirty years.

Some of Holmyard's textbooks were phenomenally successful. His *Elementary Chemistry*, first published in 1925, was reprinted eleven times by 1933, eventually selling over half a million copies worldwide (Holmyard 1925a). Even today, when chemistry has undergone so many profound changes, it remains a remarkably interesting book. The frontispiece is an extract of a dialogue between master and pupil from *Ye Booke of Allchimye* written in the twelfth century, its first two chapters address the questions of what chemistry is and how it arose, and the book ends with biographical notes on some famous chemists. Few, if any, modern elementary school chemistry texts begin by introducing pupils to the complex, multicultural origins of the discipline, provide illustrations of Arabic chemical operations, review the multiple uses and benefits of chemistry and explain how chemistry itself came to be so called. While what follows these opening chapters is a well-ordered presentation of familiar information about the occurrence, preparation, properties and uses of the chemical elements and their compounds, few readers would have failed to find something of interest even when this was incidental to the main text. For one reviewer, the book revealed Holmyard's 'adventurous and at once recognizable style' along with his 'store of humorous delights on chemistry' (J.Chem.Ind. 1934, p.882). His *Chemistry for Beginners* prompted another reviewer to comment that 'Mr Holmyard's books always please us', adding that 'he had the rare gift of writing so as to interest the young' (J.Chem.Ind. 1931, p.146).

No less successful as a publication and equally well received by the book's reviewers was his *A Higher School Certificate Inorganic Chemistry* which appeared in 1939. For one reviewer, the reading and re-reading this book had been 'sheer delight', adding that it was 'not possible to write of it save in terms which appear exaggerated'. For the journal *Nature*, it was simply 'excellent'. Following the replacement in 1951 of the system of School Certificate Examinations by the O- and A-level examinations of the GCE, Holmyard collaborated with W. G. Palmer[13] to produce in 1952 a revised edition, entitled *A Higher School Inorganic Chemistry.* The above reference to the truthfulness of ships' surgeons will be found on page 272 of the first edition and page 275 of the revised volume. Referring to the salvaging of 30 tons of mercury from a Spanish wreck off Cadiz by HMS Triumph in 1810, the reader is told that the symptoms of mercury poisoning quickly became evident among the crew and livestock of the salvage vessel. Lest any should doubt the word of the ship's surgeon, quoted in the text, that he 'had seen mice come into the ward-room, leap up to some height, and fall dead on the deck', the reader is referred in a footnote to the quotation cited above. In a discussion of the colloidal state on page 147 of the earlier volume, the poet Keats is invoked to describe a gel as 'soother than the creamy curd', a description challenged by the footnoted observation that Shakespeare says 'Out vile jelly!' The likening of the smell of phosphine to that of garlic prompts the comment (p.373) that this is 'A base libel on a plant recommended by the Father of Chemistry, HERMES, to ODYSSEUS, as an antidote to the poisons of CIRCE'.[14] A reference to 'saltpetre', potassium nitrate, is amplified by a note that the word means 'rock salt' and that this is itself a 'reminder that in bygone days chemists have found it very difficult to distinguish between substances of similar appearance' (p.216). Elsewhere (p.9), the reader is told that, in France, nitrogen is called azote (a name that

[13] Palmer was a Fellow of St. John's College, Cambridge, when Bradley (see note 5) was an undergraduate and gave him 'a taste for the history of chemistry' (Bradley *op.cit.*, p.1). Holmyard also collaborated with Frederick Arthur Philbrick to produce *A Textbook of Theoretical and Inorganic Chemistry* (Philbrick and Holmyard 1956). Philbrick died at a comparatively early age. Holmyard may have felt the need for collaboration since he had given up his post at Clifton College in 1940 when the school was evacuated to the relative safety of Bude in Cornwall. Although Philbrick is identified as the lead author, the book 'was mostly Holmyard, Philbrick having been responsible for bringing later editions up to date' (Francis 2004, p.15).
Holmyard subsequently took up the editorship of the magazine *Endeavour*. Published by ICI, the magazine sought to publicise British scientific and technological achievements. Intended as a war time publication, it proved so successful under his editorship that it continued after the war ended when it was produced in five languages (English, French, German, Italian and Spanish). Holmyard remained its editor until 1954. His obituary was published in *Endeavour*, 73, January 1960.

[14] Holmyard believed strongly in the merits of a classical education, encouraging boys to study classics before taking up chemistry in the upper school and he made frequent use of classical analogies, e.g., the 'passion of Hydrogen and Oxygen for one another causes as much trouble in the chemical world as that of Paris for Helen did in ancient Troy'.

indicates that the gas will not support combustion) and that the element cobalt is supposed to get its name from the German *Kobold*, a mischievous subterranean gnome that haunted the mines from which the ore was extracted (p.508). All these references also appear in the 1952 publication, although the pagination is slightly different.

Holmyard's output as an author of school textbooks was not restricted to chemistry. *Science: an introductory book* was published in 1926, *General Science* appeared the following year and a three volume series (*Physics/Chemistry/ Biology for Beginners*) was published in 1930 (Holmyard 1930a,b,c). Intended for the first two years of secondary schooling, a reviewer of the series in *The School Science Review* welcomed it as 'three very excellent books', adding that it was 'a pleasure to meet school textbooks which are not pervaded by an atmosphere of public examination syllabuses' (SSR 1930, p.190). In the 1930s, Holmyard also co-authored *Electricity and Magnetism for Beginners* (Badcock & Holmyard 1931), *Heat, Light and Sound for Beginners* and *Mechanics for Beginners* (Barraclough & Holmyard 1931), published as part of a Modern Science Series. Badcock and Barraclough were two of Holmyard's colleagues at Clifton and he collaborated with a third Clifton colleague to write *Elementary Botany* (Graham & Holmyard 1935). He also edited J.A. Thomson's' two volume *Biology for Everyman* (Thomson & Holmyard 1934) and was one of the editors of an eight volume *History of Technology*, published between 1954 and 1984 (Singer *et al.* 1954-84).

Why were so many of Holmyard's historicized school chemistry textbooks such successful[15] publishing ventures? To some extent, his success stemmed from a clarity of style that allowed him to express complex ideas in ways that young pupils could readily access. One reviewer of his *Elementary Chemistry* described it as 'written in English which any boy can understand - the sort…which one seldom finds in a textbook' (SSR 1925b, p.140). Recalling his schooldays at the Crypt School in Gloucester, Keith Francis, a school teacher who graduated in physics from Cambridge in 1956, described Holmyard as having a 'spicy' literary style that 'grabbed me' (Francis 2004, p.15).[16] Holmyard's obituarist in *Nature* judged that 'many students' of the journal 'must owe their introduction to chemistry' to his inorganic and organic chemistry textbooks which presented the basic facts of chemistry 'as an experimental science, relating them to general principles in a way which gives them significance and interest' (Partington 1959, p.1360).

---

[15] Although Holmyard's textbooks seem always to have been reviewed very favourably, reviewers were usually able to identify some matters that needed attention. Almost all of these related to a few typographical/proof reading errors or other relatively minor defects. One notable exception was a reviewer of Holmyard's *A Junior Chemistry* (Holmyard 1933). While writing that the book would be 'read with delight by any boy or girl without any need for external stimulus', the reviewer wondered whether 'a boy of 14…may be aggravated by the use of an appeal in the second person singular and of exclamation marks' (SSR 1933, p.126).

[16] Francis also describes Philbrick and Holmyard's *Theoretical and Inorganic Chemistry* as a 'treasure' and recalls how, as a thirteen year old pupil, it enabled him to know everything that Tarzan [the nickname of his chemistry teacher!] wanted to teach him (Francis 2004, p.15).

In addition, although the illustrations in Holmyard's books were in black and white rather than colour, they were always carefully chosen, well-related to the narrative and often appeared for the first time in texts intended for school use.

> The plates and pictures are delightful and make the book very attractive; after seeing page 73 all our boys will want to get out and collect marsh gas –which is as it should be! (*idem.*).

> The illustrations are admirable and almost all unfamiliar (SSR 1933, p.126)

His textbooks also had a readily discernible structure that enabled information to be easily located and, if necessary, retrieved for homework or revision purposes. This became increasingly important as the numbers of candidates attending grant-aided secondary schools and entered for public examinations both increased in the interwar years. The number of pupils attending grant-aided secondary schools increased from 269,887 in 1919 to 470,003 by 1938, although by no means all of these completed their secondary schooling.[17] Aided by grants from the Board of Education, the number of 'advanced', i.e., sixth form, courses in science also increased. By 1938, physics and chemistry each accounted for just under one third of all entries for the Higher School Certificate Examination taken at the end of secondary schooling; the biological sciences (botany, zoology and biology) had yet to establish a secure place in the curriculum of many secondary schools, especially those for boys (Jenkins 1979).

The long publishing history of many of Holmyard's textbooks was also facilitated by the fact that school examination syllabuses in chemistry and physics in England underwent astonishingly little change between 1918 and the curriculum reform movement of the 1960s. Save for the replacement of Imperial units by the centimetre-gramme-second (cgs) system, examination questions in physics set in the 1920s first appeared in much the same form over a generation later. In chemistry, candidates continued to be examined on their detailed knowledge of the manufacture, preparation and properties of the elements and their compounds with questions following a standard format year after year (Jenkins 1979, p.293). In Bassey's judgement, Ordinary level chemistry texts had followed 'one familiar and well-worn path' which, by 1960, had become 'a rut rather than a highway' (Bassey 1960, p.14).[18] There is little doubt that this judgement can be applied, although to a lesser extent, to school texts in physics and biology and those intended for more senior secondary school students.

Holmyard was also able to call upon his experience both as a teacher and as an examiner for the former Northern Universities Joint Matriculation Board (NUJMB). Indeed, the preface to his *A Higher School Certificate Inorganic Chemistry* informs the reader that

---

[17] These figures need to be set alongside the much larger number of pupils who attended public elementary schools in England and Wales: 5,933,458 in 1920-21 and 5,087, 485 in 1937-38. The division between elementary and secondary education reflected significant differences in social class. It was only after the Education Act of 1944 that all pupils passed from a primary to some form of secondary schooling (grammar, secondary modern or technical).

[18] Bassey used Holmyard's *Elementary Chemistry* as 'the standard treatment' with which to compare other school chemistry texts in print at the time of his survey.

‘the allotment of space to individual topics is roughly in proportion to the frequency with which these topics appear in the examination papers’, although he is very careful to make clear that more is needed in any textbook that ‘aspires to do something more than cram’, an aspiration that one reviewer readily acknowledged.

> The author is no Polyphemus and his other eye has watched the cultural aspect of chemistry to prevent the work from degenerating into a mere cram book (J.Chem.Ind. 1940, p.50).

Holmyard’s footnotes and historical commentaries were an integral part of this ‘something more’ and it would be a serious error to dismiss them as idiosyncrasies or regard them as mere ornaments intended to display the author’s undoubted erudition. Footnotes and comments they may be, but they formed part of a coherent and distinctive volume that enlivened, enriched and contextualised school chemistry and its nomenclature, then far from standardised, in ways that have not been matched. No one reading Holmyard’s texts can avoid learning something of the many roles that chemistry has played and continues to play in recorded history. Reading them today indicates just how much has been lost from chemical education.

Historical Approaches: The Wider Context

Holmyard was by no means the first to argue for a historical approach to the teaching of school science nor was he alone among his contemporaries in writing historicized chemistry textbooks (e.g., Partington, Cochrane, Lowry).[19] As long ago as 1855, the President of the British Association for the Advancement of Science, the Duke of Argyll, told his audience in Glasgow that what was wanted in the ‘teaching of the young, is not so much the mere results, as the *methods* and, above all, the *history of science’* (BAAS 1856, p.*lxxxiii*). Nor was Holmyard to be the last: over a century and a half later, the history of science featured in a national curriculum introduced for the first time in England (DES 1989). Even more recently,

[19] J. A.Cochrane’s *Readable School Physics* (1923) and his *School History of Science* (1925) were highly successful publications, both of which have recently been made available once again. The former was part of a Natural Science Series published by Bell and edited by Holmyard. J.R.Partington, professor of chemistry at the University of London, had studied with Nernst and was the author of advanced chemistry textbooks, of *A Short History of Chemistry* (1937) and of a four volume history of chemistry (Partington 1961-4). His elementary text, *Everyday Chemistry*, is divided into three parts of which the first is entitled ‘Historical and Theory’ (Partington 1929). A reviewer of Partington’s *A College Course of Inorganic Chemistry* (1939) warned his readers that ‘Professor Partington has written so many books that have been distinguished by their lucidity and accuracy that a reviewer reading a new book by him begins by being prejudiced in his favour’ (J.Chem. Ind. (1939) 58 (44), p.974. A similar comment might well have been made of Holmyard. In 1965, the year of his death, Partington was awarded the George Sarton medal. Thomas Martin Lowry FRS, worked with H.E.Armstrong from 1896 to 1913 and later became professor of physical chemistry at Cambridge. With J.M. Brønsted, Lowry introduced a new and broader definition of acids and bases. Lowry’s generously illustrated *Historical Introduction to Chemistry*, first published in 1915, presents ‘a historical account of the more important facts and theories of chemistry, as these disclosed themselves to the original workers’ (Lowry, 1915, preface). Although perhaps more appropriate for teachers than school students, the book is a further indication of the steady stream of educators who have regarded the history of science as an important component of science education.

the European Commission has argued that 'a renewed pedagogy' which presents 'the processes and methods of science together with its products' is essential for the 'Future of Europe' (EC 2007, p.16).

Among Holmyard's contemporaries, Edgar Fahs Smith (1854-1928) in the USA, chemist and author of biographies of several American chemists (Smith 1914), was said to be 'fond of theories in an historical way, but used the luxury of their downfall by experimental observation to illustrate the fallacy of theories'. This quotation is cited in Fowles who attributes to Smith the expression 'Facts remain, theories may change overnight' (Fowles *op.cit.,* pp.516-7). Among Fahs's successors in the USA, Conant's *Case Histories* (Conant *et al.*, 1957; see also Conant 1947), the *Harvard Project Physics* (1970), the *National Science Education Standards* (NRC, 1995), *Benchmarks for Science Literacy* (AAAS 1993), the textbooks of Taylor (1941/1959) and Rogers (1961) and initiatives such as McComas's use of historical examples to illustrate key aspects of the nature of science (McComas 2008), all testify to the enduring appeal of the history of science as a pedagogical tool. Given the profound changes that have taken place in science, philosophy, psychology and society since science was first schooled in the mid-nineteenth century, this widespread and enduring desire to call upon the history of science to illustrate something of the 'nature of science' calls for some comment.

Holmyard's historical approach to teaching science should not be equated with simply incorporating biographical or other elements of the history of science within school science curricula, an accommodation with which many science teachers would have felt much more comfortable and which seems to have met with more success. However, an inadequate knowledge of the history of science and its attendant risk of an unhelpfully Whiggish approach to history were problems common to both. In addition, as Brush was to suggest later (Brush 1974), introducing students to the history of science might not accord with a desired canonical account of scientific discovery. Even so, whether as a pedagogical approach or as a component of a school science curriculum, the history of science is a striking feature of the history of school science education. Why is this?

Part of the answer may lie in the fact that renewed calls to attend to the history of science have often coincided with a perception that the school science curriculum is in difficulty or facing challenges that prompt a need for reform. As noted above, the desire in the inter-war years to 'humanise'[20] school science by teaching the history of science owed

[20] For a historical perspective on the humanist critique of the place of science in the school curriculum, see Donnelly 2002, Donnelly 2004, and Donnelly and Ryder 2011. See also Mayer 2005. For a discussion of science as humanism in Denmark in the 1950s, see Lynning (2007). It is worth noting that there have been frequent calls to 'humanize' other abstract disciplines, e.g., economics (Solterer 1972) and mathematics (Guting 2006). Indeed the word 'humanizing' has perhaps acquired something of an Alice in Wonderland quality, writers taking it to mean what they wish it to mean. In 1924, the author of an article in *The North American Review* asked 'By the plain light of noon, what is implied in "humanizing" science?' (Glaser 1924, p.230). Today, as searching the Web reveals, the science education literature is replete with references to humanizing school science education, offering a variety of rationales and strategies for bringing it about. See, for example, Watts and Bentley (1994), Kipnis (1998) and Clough (2009).

much to the feeling that in making possible the unparalleled slaughter of the First World War, science –and chemistry in particular- had lost a sense of moral purpose that it urgently needed to regain. The emphasis on science in Germany came to be seen not only as having led to economic prosperity but also to the moral collapse, responsible for the war in which the Allies had been engaged. Restoring that sense of purpose seemed to require reform of the school science curriculum and the history of science pointed a way forward.

> …the teaching of science must be vivified by a development of its human interest, side by side with its material and mechanical aspects… [and] it must never be divorced from those literary and historical studies that touch most naturally the heart and the hopes of mankind (Natural Science in Education 1918, para.3).

The contrast with the aftermath of the Second World War is striking.[21] Despite the advent of nuclear war, science and technology emerged from that war with their prestige greatly enhanced. The consequent demand for reform of school science education was governed by the urgent need to increase greatly the supply of qualified scientific and technological personnel, both for civilian and, at the height of the Cold War, military purposes (Rudolph 2002). The history of science was seen as, at best, only marginally relevant to achieving this goal. Supported by a psychology that favoured 'learning by discovery', the emphasis in what became a global movement for science curriculum reform was captured by Bruner's claim that 'a schoolboy learning physics *is* a physicist' (Bruner 1960, p.14), a claim repeated by Harlen with respect to primary education in the UK almost forty years later: '*Learning science* and *doing science* proceed in the same way' (Harlen 1996, p.5). In the USA, students following *ChemStudy* courses were promised that they would 'see the nature of science' by engaging in scientific activity' and thereby to 'some extent' become scientists themselves (Pimentel 1960, p.1 and preface). In the United Kingdom, despite an assertion [22] by the Science Masters' Association and the Association of Women Science Teachers that science was an 'active humanity' (SMA 1961, p.5), canonical science was to be presented in a way that enabled students to 'think in the way practising scientists do' (Halliwell 1966, p. 242). Much that followed, such as *Process Science* and *Science in Process,* also sought to introduce students to the nature of science by involving them in suitable practical, laboratory-based exercises designed to encourage the acquisition of those allegedly discrete skills and processes (communicating, interpreting, observing, planning investigations etc.) that in sum enabled them 'to be good at science (Coles 1989, pp.4-5).

---

[21] However, at least one prominent science educator felt much the same about the role that science was also playing in the Second World War. See Westaway's *Science in the Dock: Guilty of Not Guilty?* (1942).

[22] For the Science Masters' Association, if more emphasis were placed upon the cultural and humanistic sides of science education, this might not only lead more young people to study science but also encourage them to favour science teaching as a career (SMA 1957).

During the 1960s, it gradually became clear, both in the UK and the USA, that the large scale efforts to reform school science education had not succeeded in increasing, or in some cases even stemming, the numbers of young people wishing to study the physical sciences, especially physics, beyond compulsory schooling. In England, the Council for Scientific Policy set up a committee, chaired by the eminent chemist Frederick Dainton,[23] to 'examine the flow of candidates in science and technology into higher education' (Council for Scientific Policy 1968). Although the committee's conclusion that there was a 'swing from science' in schools was soon challenged (e.g., McPhemon 1969), it received widespread publicity (e.g., AAAS 1968) and prompted a wide range of research studies of possible causes of the 'swing' away from what have become known as the STEM subjects. Such causes remain the focus of on-going investigation in many countries (Sneider 2011). In the USA, it was clear as early as 1963 that the PSSC course had attracted 'only about 4% of the two and a half million senior students in high school, and the total fraction taking *any* physics course was under 20%, and relatively shrinking' (Holton 2001, p.2). Once again, the history of science was seen as one way of easing, if not overcoming, the problem. Holton, in a review of the *Harvard Project Physics* course, has recalled how he and others were invited to a meeting by the National Science Foundation at which they were asked

> who would come to the aid of the country? For in those days it was thought without more science-literate students the Russians might get us (*idem.*)

Holton's answer eventually led him to become the principal investigator of *Harvard Project Physics* and thereby to develop a 'humanistic, historically oriented course for schools' that presented physics, as in his original text (Holton 1952), 'not just as one damned thing after another, but a coherent story of the result of the thoughts and work of living beings' (Holton 2001, p.2). The outcome was the sort of course that Holmyard would have welcomed, especially the illustrations taken from seminal documents in the history of science that appeared in the course book. Interestingly, the initial reaction of the National Science Foundation to the fact that course wasn't going to be pure physics was one of 'horror'! By the time the final edition of the book was published in 1970, there was significant evidence that it was having an impact on the numbers of students studying physics at high school and college. As many as 300,000 students per year were studying some or all of the course materials and the percentage taking physics, particularly among women students had increased markedly, 'with some 20% of all high school students taking *Project Physics,* and in use also in some colleges' (Holton 2001, p.4).

Although further growth of *Project Physics* in schools (the reference to Harvard in the title was abandoned amid concerns over 'elitism!') fell foul of the phasing out of sections of federal support for science education in the 1970s, especially funds for science teacher

[23] Dainton, speaking in 1971, used the memorable phrase 'voluntarily withdrawn from human contact; disassociating himself from personal and societal problems… a man who is "objective" to an objectionable degree', to describe how scientists were widely perceived at the time (Dainton 1971, p.18).

education, it acquired a new lease of life when the USA once again sought to reform school science education, this time by prioritising the need for a scientifically literate citizenry, although a number of other factors were involved, e.g., the demand from teachers for a revised and up-dated version of the project materials and the need to improve the understanding of physics on the part of a new generation of physics teachers. As noted above, the AAAS *Benchmarks for Science Literacy* (AAAS 1993) and the *National Science Education Standards* (NRC 1996) both attached importance to the history of science. The former included an entire chapter devoted to 'Historical perspectives' (chapter 10) while the latter advised standards for the history of science from K4-12. The revised edition of the earlier text, published in 2002 under the title *Understanding Physics* (Cassidy, Holton and Rutherford 2002), was described by Holton as the 'completion of a great circle, spanning four decades, from the first draft in 1962…through the slough of the early 1980s and now on to the rising of the new Phoenix' (Holton 2001, p.6).

That circle offers an interesting example of how a federally funded history of science initiative in the USA, initially prompted by manpower and defence concerns, came to be recast and called in aid of the perceived national need to promote science for all and enhance the general level of scientific literacy. There are some parallels here with the United Kingdom, not least in the political anxiety about scientific literacy and the levels of public understanding of science, although the picture is complicated by profound differences in the education systems of the two countries and, more particularly, by the development of a non-selective system of secondary schooling and the subsequent introduction of a statutory national curriculum in England and Wales in 1989. By requiring all students to study science from the age of 5 to 16, it was hoped that this would in due course both promote scientific literacy and develop a larger cohort of students choosing to study science, especially physical science, beyond compulsory schooling. The UK government clearly saw compulsion as a more effective policy initiative than the large scale curriculum reform of a generation earlier. Despite this, the initial version of the national curriculum included a component (known as an Attainment Target) that drew upon contemporary views from both the history and the sociology of science. Its inclusion prompted the editor of the *British Journal for the History of Science* to offer the following somewhat slightly anxious comment.

> The overriding statement of intent…is one that might be welcomed by the most radical exponent of the view that scientific knowledge is shaped by social, economic and political context (BJHS 1990, pp.1-2).

In the event, the first version of the national curriculum almost immediately proved unworkable and very little of the history of science survived into the revised statutory science curriculum introduced in 1991, or indeed into the several revisions that have taken place since (Donnelly *et al*. 1996; Donnelly & Jenkins 2001). It has largely been left to individuals and non-governmental sources to take initiatives to promote the history of science in science education.[24]

[24] For example, the *Perspectives on Science* course developed at Rugby School in Warwickshire (www1.edexcel.org.uk/Project/POS-Briefing.doc) and the Public Understanding of Science course

Advocacy of the history of science in aid of science curriculum reform may also owe much to historians of science themselves. Holmyard and Holton stand as two obvious examples, from different generations and countries, of scholars in the history of science giving attention to the form and content of school science curricula. Their pedagogical interest, however, is part of a much longer-standing and wider interest among their fellow professionals that has been well-described by Brock (1989) and Sherratt (1980). There has been an equally long-standing interest on the part of many school science teachers in the history of science and in the contribution that it might make to their teaching. Practising and former science teachers were among the founding membership of the British Society for the History of Science in 1946 and their professional association, The Science Masters' Association and its successor from 1963 onwards, the Association for Science Education, collaborated with the BSHS in a variety of curriculum and policy initiatives (Brock 1989, p.33 *et seq.*). In addition, history of science books were regularly reviewed in *The School Science Review* and the titles included in the suggested list of *Science Books for a School Library* issued from time to time as a supplement to the Association's journal.

The motives of both organisations and their members in promoting collaboration are, as always, historically contingent. Closer involvement with the work of the schools has had the advantage of bringing the history of science to the attention of teachers and students who, in turn, were able to take advantage of historical expertise to their mutual benefit. This no doubt was an important consideration, especially in its early years, for the Department of the History and Methods of Science at University College London which directed its efforts 'chiefly at science teachers and thus at secondary education' (Mayer 1999, p.233). On some occasions, notably in the inter-war years, the rhetoric underpinning this mutual interest related strongly to humanising science teaching and to re-asserting the cultural value of science. At other times, the language has been that of bridging the 'two cultures' identified by Snow in his 1959 Rede lectures (Snow 1959 and 1964), although the emphasis upon science as a 'humanity' has never been lost (Council for Scientific Policy *op. cit.,* para.181). Most recently, the history of science has been cast as an element of the 'nature of science' which has come to figure so prominently in science curricula across the world, while pedagogy (McComas 1998) and the form and practice of scientific research have become fields of scholarly academic interest to historians of science (Kaiser 2005). That is perhaps another 'great circle' that is in the process of being completed.

Conclusion

How might Holmyard's work be viewed in the light of the changes outlined above? Among his alchemical studies, his work on Geber[25] was of seminal importance and like all sound

developed at the University of York (http://www.nuffieldfoundation.org/science-public-understanding), both accessed 30th January 2012.

[25] Geber is the Latin equivalent of Jâbir and the name was used by the author of an influential series of alchemical texts in the 14th and 15th centuries. It seems likely that this Latinized version of the name was adopted by a Western writer in order to heighten the authority of his own work: Holmyard's

scholarship, his research as a historian of science has provided a platform upon which other scholars have been able to build. J.R.Partington, himself a distinguished historian of chemistry and textbook author, judged that Holmyard's alchemical studies were of 'permanent value'. Noting that alchemists and early chemists believed that metals were composed of mercury and sulphur, Partington drew particular attention to Holmyard's finding that this theory, promoted by Geber, derived from a statement in Aristotle's 'Meteorology' (Partington 1959). Holmyard's 1957 book, *Alchemy,* was published in several languages, reprinted in 1990 and remains an important and readable survey of the subject. His obituarist in *Ambix* offers an useful overview of Holmyard's alchemical studies and comments that he added to 'our knowledge of this subject…its great names, its theories, its experiments and its apparatus'. His conclusion is that Holmyard brought about 'a greater interest in and an improved understanding and appreciation of the work and writings… of ...Muslim chemists in general' (McKie 1960, p.5).

Although Holmyard's school chemistry textbooks were written for syllabuses and examinations that differ greatly from those confronting students in the early years of the twenty-first century, they remain an important model for any author wishing to present chemistry, not simply as a discipline, but as an integral part of a wider cultural history. Reading some of his textbooks helps the reader understand that interest in the behaviour of materials and the desire to understand how they may be changed from one to another is at least as old as recorded history. At the end of a chapter entitled 'How Chemistry Arose', Holmyard invites the reader of his *Elementary Chemistry* to answer questions such as the following.

> Mention some of the chemical facts and processes known to the Ancient Egyptians.
>
> Explain how it was that the Muslims were able to establish chemistry on a sound basis.
>
> Who was Paracelsus? What service did he render to chemistry?

Anyone who follows the historical journey that Holmyard sets out so skilfully in his texts will therefore travel with him to China, India and Arabia as well as within Europe, glimpsing other languages and cultures on the way and learning that it is all too humanly possible to take a wrong turning while firmly believing it is the way forward. The journey that he offered was much less familiar in the first few decades of the twentieth century than is the case today when societies have become much more multicultural and scholars more aware of non-Western contributions to the development of science.

Although Holmyard's evolutionary approach found limited favour, his advocacy did much to draw attention to the contribution that the history of science could make to school

---

'likely guess' (Holmyard 1957, p.134) was that these later mediaeval works were written by a European scholar, possibly in Moorish Spain. Holmyard was able to identify the eighth century alchemist Jâbir ibn Hayyân who held a court appointment under the Caliph Harun al-Rashid. A lengthy examination of the 'Geber problem' is available at www.history-science-technology.com science education and to encourage teachers to incorporate historical components within their teaching. In doing so, the various attempts to 'humanize' school science teaching presented challenges and problems that have a contemporary international relevance as attempts are made to accommodate the history of science within the movement to promote the teaching of the 'nature of science'. As experience with *Harvard Project Physics* confirmed, addressing and overcoming these challenges and problems requires a substantial investment in science teachers' professional development that is grounded in collaboration between those whose scholarly expertise lies in the history of science and those teaching science in schools. That can succeed only if there is agreement about the contribution that the history of science can legitimately make to the science curriculum and if science teachers enable their students to think historically as well as scientifically. Fortunately, the form and content of that contribution are now matters not only for lively but well-informed debate but also for science curriculum development (e.g., Holton 2003; Matthews 1994 and 2009; Kokkotas, Malamista & Rizaki 2009).

Edgar W. Jenkins is Emeritus Professor of Science Education Policy at the University of Leeds where he was Head of the School of Education (1980-84 and 1991-95) and Director of the Centre for Studies in Science and Mathematics Education (1997-2000). From 1984 to 1997 he edited the research review journal *Studies in Science Education*. His principal books include *From Armstrong to Nuffield* (1979); *Technological Revolution?* (1986); *Inarticulate Science?* (1993); *Investigations by Order* (1996); *From Steps to Stages* (1998); *Learning from Others* (2000) and *Science Education, Policy, Professionalism and* Change (2001). He has recently (2013) co-edited a volume to mark the fiftieth anniversary of the founding of the Association for Science Education.

REFERENCES

American Association for the Advancement of Science. (1968), British Youth Swings Away from Science, *Science,* 15 March 1968, 1214-15.

American Association for the Advancement of Science. (1993), *Benchmarks for Science Literacy: Project 2061,*Oxford University Press, New York.

Armstrong, H.E. (1903) *The Teaching of Scientific Method and Other Papers on Education*, London. Macmillan.

Badcock, W.C. & Holmyard, E.J. (1931), *Electricity and Magnetism for Beginners*, J.M. Dent, London.

Barraclough, F. & Holmyard, E.J. (1931), *Mechanics for Beginners*, J.M. Dent, London.

Bassey, M. (1960), A Field review of O-level Chemistry Textbooks, *Technical Education and Industrial Training*, 2 (12),11-15.

BJHS. (1990), Editorial, *British Journal for the History of Science,*23,1-2.

Blackwood's Magazine. (March 1916), *Editorial*, 407-18.

Bradley, J. (1988), *They Ask for Bread: an essay on the teaching of chemistry to young people*, North Ferriby, North Humberside, Privately published.

British Association for the Advancement of Science. (1856), *Report of the Annual Meeting,* John Murray, London.

Brock, W.H. (1973), *H.E.Armstrong and the Teaching of Science 1880-1930,* Cambridge, University Press, Cambridge.

Brock, W.H. (1989), Past, Present and Future. In M. Shortland and A. Warwick (Eds.), *Teaching the History of Science*, BSHS, Blackwell, Oxford, 30-41.

Brock, W.H. (1996), *Science for All*, Ashgate Publishing, Aldershot.

Brown, J. (1925), *Teaching Science in Schools,* University of London Press, London.

Browne, C.E. (1954), *Henry Edward Armstrong,* Harrison and Sons (privately printed), London. Re-issued in 1966 with a memoir of Browne as *Henry E. Armstrong and Charles E. Browne,* Harrison and Sons for Christ's Hospital, Horsham.

Bruner, J. (1960), *The Process of Education*, Harvard University Press, Cambridge, MA.

Brush, S. G. (1974), Should the history of science be X-rated? *Science*, 183, 1164-72.

Cassidy, D., Holton, G. & Rutherford, J. (2002), *Understanding Physics.* New York, Springer-Verlag-New York.

Cawthorne, H.H. (1930), *Science in Education: Its Aims and Methods*, Oxford University Press, London.

Clough, M.P. (2009), *Humanizing science to improve post-secondary science education,* Paper presented at the 10th IHPST Conference, Indiana, June 24-28th.

Cochrane, J.A. (1923), *Readable School Physics,* Bell and Sons, London.

Cochrane, J.A. (1925), *School History of Science*, Edward Arnold, London.

Coles, M. (1989), *Active Science,* Collins Educational, London.

Conant, J.B. (1947), *On Understanding Science: An Historical Approach*, Yale University Press, New Haven.

Conant, J.B. *et al.* (1957), *Harvard Case Histories in Experimental Science*, Harvard University Press, Cambridge, MA.

Council for Scientific Policy (1968), *Report of an Inquiry to Examine the Flow of Candidates in Science and Technology into Higher Education*, HMSO, London.

Dainton, F.S. (1971), *Science: salvation or damnation?* University of Southampton, Southampton.

DES (1989), *Science in the National Curriculum,* DES/WO, London.

Donnelly, J.F. (2002), The 'humanist' critique of the place of science in the curriculum in the nineteenth century and its continuing legacy, *History of Education*, 3 (6), 535-555.

Donnelly, J.F. (2004), Humanizing Science Education, *Science Education* 88 (5), 762-784.

Donnelly J.F., Buchan, A., Jenkins, E., Laws, P & Welford, G. (1996), *Investigations by Order: policy, curriculum and science teachers' work under the Education Reform Act*, Studies in Education, Nafferton, East Yorkshire.

Donnelly, J.F. & Jenkins, E.W. (2001), *Science Education: policy, professionalism and change,* Paul Chapman, London.

Donnelly, J.F. and Ryder, J. (2011), The pursuit of humanity: curriculum change in English school science*, History of Education*, 40 (3), 219-313.

European Commission (2007), *Science Education NOW: A Renewed Pedagogy for the Future of Europe,* Directorate General for Research, Brussels.

Fowles, G. (1937), *Lecture Experiments in Chemistry,* Bell and Sons, London.

Francis, K. (2004), *The Education of a Waldorf Teacher*, iUniverse, Inc., New York.

Freund, I. (1904), *The Study of Chemical Composition: an account of its method and historical development,* Cambridge University Press, Cambridge.

Glaser, O. (1924), On Humanizing Science, *The North American Review*, 219 (819), 230-239.

Graham, A.P. & Holmyard, E.J. (1935), *Elementary Botany*, J.M.Dent, London.

Guting, R. (2006), Humanizing the teaching of mathematics, *International Journal of Mathematics Education in Science and Technology*, 11 (3),415-425.

Halliwell, H.F. (1966), Aims and action in the classroom, *Education in Chemistry,* 3 (15), 242-246.

Hansard (18 July 1916), 5 (84), col. 906

Harlen, W. (1996), *The Teaching of Science in Primary Schools*, David Fulton, London.

Hartley, H.B. (1971), *Studies in the History of Chemistry*, Clarendon Press, Oxford.

Harvard Project Physics. (1970), *The Project Physics Course*, Holt, Rinehart and Winston, New York.

Holmyard, E.J. (1922), *Inorganic Chemistry: A Textbook for Schools and Colleges*, Edward Arnold, London.

Holmyard. E.J. (1924a), The Historical Method in the Teaching of Chemistry, *School Science Review,* V (20), 227-233.

Holmyard, E.J. (1924b), *The Teaching of Science*, Bell and Sons, London.

Holmyard, E.J. (1925a), *An Elementary Chemistry,* Edward Arnold, London.

Holmyard, E.J. (1925b), Historical Method in School Science Courses, *Journal of Education and School World*, July, 490.

Holmyard, E.J. (1925c), *Chemistry to the Time of Dalton,* Edward Arnold, London.

Holmyard, E.J. (1926), *Science: an introductory book*, J.M. Dent, London.

Holmyard, E.J. (1928a), *The Works of Geber by Richard Russell 1678: a new edition with notes by E.J.Holmyard*, J.M. Dent, London.

Holmyard, E.J. (1928b), *The Great Chemists*, Methuen, London.

Holmyard, E.J. (1930a), *Chemistry for Beginners,* J.M. Dent, London.

Holmyard, E.J. (1930b), *Physics for Beginners*, J.M. Dent. London.

Holmyard, E.J. (1930c), *Biology for Beginners*, J.M. Dent, London.

Holmyard, E.J. (1933), *A Junior Chemistry*, J.M. Dent, London.

Holmyard, E.J. (1939), *A Higher School Certificate Inorganic Chemistry*, J.M. Dent, London.

Holmyard, E.J. (1944), The Meaning of Science, *Endeavour*, 3,124-5.

Holmyard, E.J. (1946), *Makers of Chemistry*, Clarendon Press, Oxford.

Holmyard, E.J. & Palmer, W.G. (1952), *A Higher School Inorganic Chemistry*, J. M. Dent, London.

Holmyard, E.J. (1957), *Alchemy*, Penguin, Harmondsworth, (reprinted by Dover, New York 1990).

Holton, G. (1952), *Introduction to Concepts and Theories in Physical Science,* Addison-Wesley, Cambridge MA.

Holton, G. (2001), *The Project Physics Course, Then and Now*. Paper delivered to the Annual Meeting of the History of Science Society, November 2001.

Holton, G. (2003), What Historians of Science and Science Educators Can Do for One Another, *Science& Education,* 12 (7), 603-616.

Jenkins, E.W. (1979), *From Armstrong to Nuffield: Studies in twentieth century science education in England and Wales,* John Murray, London.

Jenkins, E.W. (2000), Who were they? George Fowles (1882-1969), *School Science Review* 82 (299) 87-89.

Jenkins, E.W. (2001), Who were they? F.W.Westaway (1864-1946), *School Science Review*, 83 (302) 91-94.

Journal of Chemistry and Industry (1931), 50 (8), 146.

Journal of Chemistry and Industry (1934), 53 (43), 882.

Journal of Chemistry and Industry (1940), 59 (3), 50-51.

Kaiser, D. (Ed.) (2005), *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives,* MIT Press, Cambridge, MA.

Kinsman, J. (1985), *The Contribution of Eric John Holmyard (1891-1959) to science education in England and Wales*. Unpublished project submitted as part of the fulfilment of the requirements of the degree of M.Sc., Council for National Academic Awards.

Kipnis, N. (1998), A History of Science Approach to the Nature of Science: Learning Science by Rediscovering It. In W.F.McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies*, Dordrecht, Kluwer Academic Publishers, 177-196.

Kokkotas, P.V., Malamista, K.S. & Rizaki, A.A. (2009), *Adapting Historical Knowledge Production to the Classroom*, Sense Publishers, Rotterdam.

Layton, D. (1984), *Interpeters of Science: A History of the Association for Science Education,* John Murray/ASE, London.

Livingstone, R.W. (1916) *A Defence of Classical Education,* London, Macmillan.

Lodge, O. (1925) Introduction. In R.H.Murray, *Science and Scientists in the Nineteenth Century*, Sheldon, London.

Lowry, T.M.1 (1915), *Historical Introduction to Chemistry,* Macmillan, London.

Lynning, K.H. (2007), Portraying Science as Humanism- A historical Case Study of Cultural Boundary work from the Dawn of the 'Atomic Age', *Science & Education*, 16 (3-5) 479-510.

Matthews, M.R. (1994), *Science Teaching: The Role of History and Philosophy of Science*, Routledge, New York.

Matthews, M.R. (2009), Teaching the Philosophical and Worldview Components of Science, *Science & Education,* 18 (6-7), 697-728.

Mayer, A.K. (1999), I have been fortunate. Brief report on the BSHS Oral History Project: the history of science in Britain 1945-65, *British Journal for the History of Science* 32, 223-235.

Mayer, A.K. (2005), When things don't talk: Knowledge and belief in the inter-war humanism of Charles Singer, 1876-1960, *British Journal for the History of Science*, 38 (3), 325-347.

McComas, W.F. (1998), *The Nature of Science in Science Education: Rationales and Strategies,* Kluwer Academic Publishers, Dordrecht.

McComas, W.F. (2008), Seeking Historical examples to Illustrate Key Aspects of the Nature of Science, *Science and Education* 17 (2-3), 249-263.

McCulloch, G. (1984), Views of the Alternative Road: The Crowther concept. In D. Layton, *The Alternative Road,* Leeds, University of Leeds Press, 57-83.

McCulloch, G. (1991), *Philosophers and Kings: Education for Leadership in Modern England*, Cambridge University Press, Cambridge.

McCulloch, G. (2006), Cyril Norwood and the English Tradition of Education, *Oxford Review of Education*, 32(1), 55-69.

McKie, D. (1960), Obituary of Eric John Holmyard, *Ambix*, VIII (1),1-5.

McPhemon, A. (1969), 'Swing from science' or retreat from reason? *Higher Education Quarterly*, 22 (3), 54-273.

Mellor, J.W. (1902), *Higher Mathematics for Students of Physics and Chemistry: with special reference to practical work*, London, Longmans, Green.

Mellor, J.W. (1932), *Introduction to Modern Inorganic Chemistry*, Longmans, Green, London.

National Research Council (1995), *National Science Education Standards*, National Academy Press, Washington.

Natural Science in Education (1918), *Report of the Committee on the Position of Natural Science in the Educational System of Great Britain*, HMSO, London.

Norwood, C. (1922), Foreword to Holmyard (1922), *op.cit.*

Norwood, C. (1929) *The English Tradition of Education*, John Murray, London.

Ogston, A.G. (1972), Harold Brewer Hartley 1878-1972, *Biographical Memoirs of Fellows of the Royal Society*, 19, 348-326.

Partington, J.R. (1929), *Everyday Chemistry,* Macmillan, London.

Partington, J.R. (1937), *A Short History of Chemistry*, Macmillan, London.

Partington, J.R. (1939), *A College Course of Inorganic Chemistry*, Macmillan, London.

Partington, J.R. (1959), Eric John Holmyard, *Nature* 184, 1360.

Partington, J.R. (1961-4), *A History of Chemistry*, St. Martin's Press, London.

Perkin, W.H. & Lean, B. (1896), *An Introduction to the Study of Chemistry,* Macmillan, London.

Philbrick, F.A. & Holmyard, E.J. (1956), *A Textbook of Theoretical and Inorganic Chemistry*, J.M. Dent, London.

Pimentel, G.C. (Ed.). *Chemistry: An Experimental Science*, Freeman, San Francisco.

Rogers, E.M. (1961), *Physics for the Inquiring Mind: The Methods, Nature and Philosophy of Physical Science*, Princeton University Press, Princeton NJ.

Rudolph, J.L. (2002), *Scientists in the Classroom: the cold war reconstruction of American science education,* Palgrave, New York.

Sadler, M. (1909), Introduction to F. Hodson (Ed.) *Broad Lines in Science Teaching,* Christophers, London. Sadler is quoting John Ruskin.

Sherratt, W.J. (1980), *History of Science Education: an investigation into the role and use of historical ideas and material in education with particular reference to science education in the English secondary school since the 19th century,* PhD thesis, University of Leicester.

Simon, B. (1974), *The Politics of Educational Reform, 1920-1940*, Lawrence & Wishart, London.

Singer, C., Holmyard, E.J. & Williams, T.I. (1954-84), *A History of Technology*, 8 volumes, Oxford, Clarendon Press.

Singer, C. (1959), Tribute to E.J. Holmyard, *The Times,* 23rd October,17.

SMA (1957), *Science and Education,* SMA/John Murray, London.

SMA/AWST (1961), *Science and Education; A Policy Statement issued by The Science Masters' Association and The Association of Women Science Teachers,* John Murray, London.

Smith, E.F. (1914), *Chemistry in America: Chapters from the history of science in the United States,* D. Appleton & Co., New York.

Sneider, C. (2011), *Reversing the Swing from Science: Implications from a Century of Research*. Paper presented at the ITEST Convening on Advancing Research on Youth Motivation in STEM, September 9-11, Boston College.

Snow, C.P. (1959), *The Two Cultures and the Scientific Revolution*, Cambridge University Press, Cambridge.

Snow, C.P. (1964), *The Two Cultures, and A Second Look: an expanded version of 'The Two Cultures and the Scientific Revolution*, Cambridge University Press, Cambridge.

Solterer, J. (1972), Towards the humanization of economics, *Revue of Social Economy,* 30 (3), 394-400.

SSR (1925a), *Review of Holmyard's The Teaching of Science*. VI (24), 265-266.

SSR (1925b), *Review of Holmyard's An Elementary Chemistry*, VII (26), 140.

SSR (1930), *Review of Holmyard's [three volumes) Chemistry/Physics/Biology for Beginners,* XII (46), 190.

SSR (1933), *Review of Holmyard's A Junior Chemistry*, XV (57), 126.

Taylor, L.W. (1949/1959), *Physics: The Pioneer Science*, 2 vols, Dover publications, New York.

The Times (1959), *Obituary of E.J.Holmyard*. October 15th, 16.

Thomson, J.A. & Holmyard, E. J. (1934), *Biology for Everyman*, J.M. Dent, London.

Tilden, W. (1919), *School Science Review* 1 (1), 12.

Turner, D.M. (1927), *History of Science Teaching in England*, Chapman & Hall, London.

Vlaeminke, M. (2000), *The English Higher Grade Schools: a lost opportunity*, Woburn Press, London.

Watts, M. & Bentley, D. (1994), Humanizing and feminizing school science: reviving anthropomorphic and animistic thinking in constructivist science education, *International Journal of Science Education*, 16 (1), 83-97.

Westaway, F.W. (1929), *Science Teaching*, Blackie, London.

Westaway, F.W. (1942), *Science in the Dock: Guilty or Not Guilty?* Scientific Book Club, London.

Williams. T.I. (2002), Clifton and science. In N.G.L.Hammond (Ed.), *Centenary Essays on Clifton College*. Bristol, 195-212.

Williams, T.I. (2004), Entry for E.J.Holmyard, *Dictionary of National Biography,* Oxford University Press, Oxford.