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The Democratic Argument for Science Curriculum Reform in Britain and Australia: 1935-1945

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Abstract

The dominance of "academicism" in science education can be shown over the last century. However in the period of this study, when access to a universal secondary education was the main thrust of social reconstruction in Britain and Australia, a key struggle was for a socially-centred general science. The struggle, concerned the terms on which "the spirit of Science alive in the world," could enter and transform education in schools to meet human needs. The epistemological arguments of the reformers were pragmatic. This study, set initially in an earlier period of depressive capitalism, is an account of how curriculum and cultural change was mediated by educational actors, employing pragmatic arguments for reform which drew on the metaphoric power of a scientific achievements which emanated from their society, to pursue democratic agendas within their workplace and locality.

In England, and later in the Colonies, the general science movement of the thirties was born in attempts to advance the claims of natural science in the public school curriculum (Fawns, 1988a; Jenkins, 1979; Layton, 1984; Kliebard, 1986; Goodson, 1980). Its supporters often appeared to concentrate on what might be called "domestic changes," on the widening and modernising of science syllabuses, and on the introduction of sensible methods of presentation for a mass audience. However, its principal proponents and defenders like Joseph Lauwerys[1], method lecturer at the London Institute of Education, raised issues of persistent significance and persistent debate about the central importance of the interpretation of scientific knowledge over scientific method in a reconception of the function of school science in social reconstruction.

Joseph Lawerys wrote the interim report of the General Science Committee of the Science Masters' Association (1936). It contained the definition of General Science which was quoted in the introduction to the first syllabus statement in Australia by the Melbourne University Schools Board (1943) and employed in the Spens (1938) and Norwood Report (1943) in establishing the conditions and form in which science was to enter mass secondary education in Australia and England:

> General Science is a course of scientific study and investigation which has its roots in the common experience of children, and does not exclude any of the fundamental special sciences. It seeks to elucidate the general principles observable in nature, without emphasising the traditional division into specialised subjects until such time as is warranted by the increasing complexity of the field of investigation, by the developing unity of the separate parts of the field, and by the intellectual progress of the pupils... (Melbourne University Schools Board, 1943 to 1959).

Lauwerys' social representations of General Science were domestic in the sense of meeting the personal needs of teacher survival and organisation but they were also evolutionary tools on the scale of human societies. This general science movement had considerable support from political liberals of that time who favoured the introduction of biology but saw science teaching's contribution to general education in terms of T. H. Huxley's (1854) scientific method, "an organised common sense" (Bibby, 1971). To Joseph Lauwerys General Science should show scientific knowledge and the scientific attitude active in the world. It marked "the growth of a revolt against the literary, linguistic and grammatical tradition which have so long dominated European education," but not, he noted "against the remnants of humanism which those traditions still retain " (Lauwerys, 1940, p. 446). In what he saw as the long overdue recasting of the educational system, Lauwerys hoped to convince the Spens Committee (1938) that a body of verified knowledge (natural science) could be a core around which a coherent liberal-democratic curriculum could be framed.

Lauwerys and others including prominent English scientists were able to revolt against the literary tradition and the poor standing of Science in liberal education in the English public school. The campaign for General Science in formulations of the curriculum for the universal secondary education in Britain and Australia at this time, was founded on arguments for social responsibility in science and for citizenship, to prepare the way for a new social order established on a sound foundation of rational humanism in education. Prior to the end of the War, it was socially and academically acceptable to admit interest in, and express admiration for, the great technical achievements of the social experiments in the USSR. Lauwreys and Bernal (1939) in England, and Ashby (1947) and Turner[2] in Australia, for example, pointed to scientific progress under socialism as evidence of the need for public policy and investment in science education. Collective mobilisation and social and economic construction in the USSR seemed to provide evidence that fundamental democratic reform was feasible, and indeed available, through public education which placed greater faith in the liberating and disciplinary spirit of science at work in the changing world. Public intellectuals with such divergent social visions as Bernal and Popper felt that education in science offered a training that was practically and morally superior.

Science, Liberal Education and the Secondary School Curriculum

In an extended footnote to his wartime work, *The Open Society and Its Enemies*, Popper (1945) expressed his frustration with the university and public school culture of the pre-war years. He responded to a definition of liberal education quoted in the 1939 edition of the Pocket Oxford Dictionary.

> It still says: "liberal (of education) fit for a gentleman, of a general literary rather than technical kind." I admit that there is a serious problem of a professional education, that of *narrow-mindedness*. But I do not believe that a "literary" education is the remedy; for it may create its own peculiar kind of narrow-mindedness, its peculiar snobbery. And in our day no man should be considered educated if he does not take an interest in science. (Popper, 1945, p. 283)

Gregory, the influential editor of *Nature* who earlier argued a "science for all" was taught because it offered "an intellectual outlook, a standard of truth and a gospel of light" (Gregory, 1916, p. iv). Like Gregory and Lauwerys, Popper saw science as the most important "spiritual movement of the day."

> Our so-called Arts Faculties, based upon the theory that by means of a literary and historical education they introduce the student into the spiritual life of man, have therefore become obsolete in their present form. There can be no history of man which excludes a history of his intellectual struggles and achievements; and there can be no history of ideas which excludes the history of scientific ideas. (Popper, 1945, p. 283)

Literary education, he argued, had not only failed to educate students to an understanding of the greatest spiritual movement of his day, but failed to educate them to intellectual honesty.

> Only if the student experiences how easy it is to err, and how hard to make even a small advance in the field of knowledge, only then can he obtain a feeling for the standards of intellectual honesty, a respect for truth, and a disregard of authority and bumptiousness. But nothing is more necessary today than the spread of these modest intellectual virtues. "The mental power," T. H. Huxley wrote in *A Liberal Education* "which will be of most importance in your life will be the power of seeing things as they are without regard to authority." But at school and at college you shall know of no source of truth but authority. (Popper, 1945, p. 284)

Popper was prepared to admit that many science courses still treated science as old knowledge. This treatment of science in education was something he, like Lauwerys, hoped would disappear in time.

> ... for science can be taught as a fascinating part of human history—as a quickly developing growth of bold hypotheses, controlled by experiment, and by *criticism*. Taught in this way, as a part of the history of "natural philosophy," and of the history of problems and ideas, it could become the basis of a new liberal University education; of one whose aim, where it cannot produce experts, will be to produce at least *men who can distinguish between a charlatan and an expert.* (Popper, 1945, p. 284)

The idea that a liberal education in universities should train the public to recognise and appreciate the contribution of professional science was also to be prominent in arguments for reform in school curricula. The suspicion scientists and science teachers in establishment schools in both England and Australia encountered in both England and Australia in their attempts to redefine the form and function of the liberal education of Matthew Arnold can be seen in C.S. Lewis' essay, *The Abolition of Man,* first published in 1943. This essay was still used as a prescribed text for all teachers in training at Melbourne University in the mid-sixties, when C. P. Snow (1964) in *The Two Cultures*, led the next attack on the liberal curriculum. Lewis wrote;

> There is something which unites magic and applied science while separating both from the "wisdom" of earlier ages. For the wise men of old the cardinal problem had been how to conform the soul to reality, and the solution had been knowledge, self-discipline, and virtue. For magic and applied science alike, the problem is how to subdue reality to the wishes of men: the solution is a technique; and both, in the practice of this technique, are ready to do things hitherto regarded as disgusting and impious—such as digging up and mutilating the dead. If we compare the chief trumpeter of the new era (Bacon) with Marlowe's Faustus, he similarity is striking. You will read in some critics that Faustus has a thirst for knowledge... The true object is to extend Man's power to the performance of all things possible. (Lewis, 1943, pp. 52-53)

A central function for the new science education in civil education and social reconstruction was being defined, in the preface of the new Biology textbooks used in England and Australia from the mid thirties (Fawns, 1988b). For example, Hatfield (1938) in the preface to his highly successful school text *An Introduction to Biology,* aligned the importance of biology teaching with social biology, and in particular with the precepts of eugenics.

> It is often asserted that, at the present stage of human development, biology has a special mission to fulfil in school education. It can awaken adolescent pupils to the relation between biological processes and their own lives, and provide them with a background for appreciating those processes in their true perspective. It can also stimulate interest in many of the wider issues now confronting humanity, which demand for their solution the application of biological knowledge

> to human affairs. Such problems as the effect on human populations of a differential birthrate, of mental disease, of increasing longevity combined with a decreasing fertility, are troubling the minds of the thoughtful in most Western civilisations. In so far as the tendencies revealed are undesirable and therefore to be combatted, they must be realised by the young, for ultimately only the young can change them. (Hatfield, 1938, p. 3)

By the late thirties, these spiritual, professional and practical social arguments lay behind the call for an expansion of school science. The social relations of Science was a prominent theme in the *Australian Journal of Science* founded in Sydney in 1938 to organise a national voice for scientists. In 1939 it announced (Ashby, 1939) the formation of the Australian Association of Scientific Workers, (ASW; Moran, 1983), based on the experiences of the English organisation established through the British Association for the Advancement of Science by Bernal and other civil minded scientists—"to secure the wider application of science and the scientific method for the welfare of society, and to promote the interests of science and the scientific profession, especially in those sciences not covered by existing professional organisations" (Ashby, 1939, p. 95). Members of the ASW, Bernal, Hogben, and Lauwerys in England, and the English Australian biologists, Ashby, Wadham, Turner and the fledgling Science Teachers Associations of New South Wales and Western Australia through Stanhope (1939) and Victoria through Turner (1940) saw General Science as an educational platform on which all with an interest in the professionalisation of scientific employment including research and teaching could briefly stand united. Through a commitment to a General Science for all in secondary schools, an education in science could be presented as the badge of utility and the key to good citizenship. There were a number of conceptual planks in their platform which embody various pragmatic responses: broadening syllabuses (to show a functional view of thought) , foregrounding the social in presentation and organisation
(a rejection of Cartesian thought), rewriting the school texts (to describe a social and experimental conception of science), fostering the scientific attitude (to present a fallibilistic view of scientific knowledge), problem method (the primacy of intellectual method), and teaching for social transfer (to point to the representative character of thinking .

The General Science Platform

Broadening of Syllabuses—To Show a Functional View of Scientific Thought

Lauwerys, like many others (Science Masters Association (SMA), 1936) found science to be represented in boys' schools by narrowly conceived and academic courses in inorganic chemistry and bits of physics. In girls' schools he found rather lady-like courses in taxonomic botany or sentimental meanderings through nature study (Jenkins, 1981). Lauwerys argued that this sort of study had been introduced in response to economic interests and educational ideals which were no longer operative. It is clear that Lauwery's broad personal interests prepared him to argue the broader social and cultural significance of science and science teaching in the grammar schools and at annual meetings of the British Association (Holmes, 1981). Lauwerys spoke of a new humanism rooted in scientific knowledge rather than mere technical knowledge. He argued for the need to modernise school science by assimilating biology. This was based on a view similar to that of Phillips and Cox, whose early method text was widely used in girls' schools in England and Australia, who found in biology "the democratic, spiritual and aesthetic principles of nature directly observed" (p. iv). Their biology teaching was aimed at giving the pupils "a reverence for nature and for natural laws, thus helping them to lead fuller lives because they would have a better understanding of, and truer contact with a world governed by these laws" (Phillips &Cox, 1935, p. iv).

Lauwerys, like Julian Huxley (1932), whom Turner regarded as a powerful member of the liberal establishment, saw in Biology a bridge to the humanities. He sought to contrast what he had in mind for biology in general science with the sentimentality of nature study courses for children and older girls by arguing from the war experience for the need to offer the fighting man essential knowledge of hygiene and healthy sex. He pointed to new economic interests and enriched experiences for grammar school boys in a scientific training in biology in managing colonial agriculture. In relation to deficiencies in the science curriculum in girls' schools he pointed to the social need in war time for public understanding of physics, chemistry and engineering. Lauwerys made the claim that "there is no reason whatever for supposing that girls *naturally* find the physical sciences more difficult or less interesting than do boys." He went on to show that he meant by "naturally,"—genetically determined, rather than socially determined—and doubted that "in the USA (where most women drive cars) girls would be more interested in cars than would English girls, or that in Russia (where women are trained as pilots) girls are more interested in aeroplanes than are girls in England." (p. 526). However, he accepted that "at and after puberty the interest of girls in the functioning of living things may grow more rapidly than that of boys" (Lauwerys, 1940, p. 526). He appears to have accepted the social necessity of mechanics for girls, whilst also accepting the biological imperatives of traditional conceptions of the nurturing role of girls in society.

Foregrounding the Social in Presentation and Organisation—A Rejection of Cartesian Thought

Lauwerys, following Nunn's (1920) and Whitehead's (1922) well respected cosmology, was critical of examination-bound tradition which prematurely emphasised "precision" over "application" and "romance." He condemned the tradition which could "sacrifice a knowledge of the functioning and social effects of heat engines to the acquisition of meretricious skill in artificial calculations on specific and latent heats" (Lauwerys, 1940, p. 527). He argued that the instruction did not seem relevant to student needs and interests; and that science teachers have not attempted to introduce science in the world. This was not a radical position. Julian Huxley (1932), a spokesman for the liberal establishment had, like his grandfather, T. H. Huxley (1854), made similar criticisms of English school masters but emphasised scientific thinking rather than technical and social benefits of science. The Headmaster of Eton, author of the Norwood Report (1943a) addressing a gathering of headmasters at this time, observed, "Science can be a thinking subject, but the formulae which guard its doors are so lifeless and so forbidding that many are deterred from trying to force an entrance" (Norwood, 1944, p. I). Lauwerys wrote bitterly of the impact of traditional science teaching methods. "Often they (the students) decided that the subject needed a special kind of mind and was best pursued by those whose desiccated personalities allowed them to ignore human affairs, or whose compendious memories enabled them to deal easily with long lists of facts or names. They turned away to other fields where their sympathies were more generously fostered and their imagination given freer scope" (Lauwerys, 1939, p. 55).

In messages directed mainly to grammar schools, Lauwerys pointed to the loss of those students whose humanistic outlook was sadly needed in science, especially in the application of science, and whose interest in men and affairs naturally led them into positions of public importance in government, in the civil service, in the professions, and in the management of industry and commerce. "Instead of acquiring the knowledge required to shape a new society, they studied subjects which made them respectful of outworn traditions, rather than responsive to changed conditions" (Lauwerys, 1939, p. 56).

The science courses Lauwerys sought to replace by general science were specialised or vocational courses. His ambition was to secure science teaching which presented a socially situated general science appropriate for all future citizens. The course of study as defined in the SMA 1935) interim report called for reorganisation that delayed the emphasis on the traditional division into specialised sciences. His science was to cover both physical and biological sciences and, if possible, an introduction to geology, astronomy and agriculture. The general science syllabus presented in the SMA's belated final report in 1938 organised the content under the traditional academic headings. Shelton[3] a prominent teacher unionist, and for a brief period a member of the SMA General Science Committee, attacked the ideological gap between the interim and final SMA reports (Shelton, 1939). Nothing it seemed was to be left out, but "a far greater mass of stuff" added. This argument was never effectively countered in England, and was a critical concern of teachers (Jenkins, 1979, p. 124). Like many reformers before and after him, Lauwerys believed the natural charm of a superior motive would transform teaching practices, enabling more effective learning by reducing resistance, boredom and alienation. However, examination papers "in practice give the lead to grammar schools and dominate other schools" (Preese, 1950). In the case of General Science at the First Certificate level the first examinations in both England and Victoria presented physics, chemistry and biology questions in separate sections. Textbooks with titles like *General Science: Chemistry,* or *General Science: Physics* (Spencer White, 1938) were popular in England and soon used in Australia in grammar schools in the late thirties.

For Lauwerys a tripartite division of General Science had what he felt was the virtue of convenience, in what he described as a "well ordered form." Lauwerys saw "the uniting of science as metaphysical, or at any rate, a purely logical idea" (p. 58) which had no relevance to classroom problems. "I do not think that the sciences are related to each other " (Lauwerys, 1939, p. 58). He claimed that teachers did not need the symbol of unity to justify or defend their social selections. They are adding, not subtracting. What was important, he felt, was that they should show the students how the sciences are related to individual and social life. Seen from a sufficient social distance, the distinctions between the sciences seemed to Lauwerys to be indiscernible or irrelevant. His argument seems to understate the teachers' traditional dependence on the textbook in presenting the liturgy and catechism of science education (Jenkins, 1979, p. 95; Westbury, 1983; Reid, 1987). The authors of general science texts, both in England (e.g., Andrade & Huxley, 1934), and in the colonies (e.g., Daniel, 1936; Daniel & Turner, 1943), refer to the virtue and the difficulty of securing "social" rather than "logical" structure, and, hence, lesson planning which would have challenged such institutionalised categories in the junior science courses. In the new domain of Biology, the institutional categories were not then fixed, and the boundaries with the other categories not settled.

Rewriting the Science Texts—To Describe a Social and Experimental Conception of Science

In England, it is clear that Lauwerys, and others, associated the humanisation of science teaching with two initiatives that were incorporated in early General Science texts.

1. the assimilation of biology into science programmes in boys' schools; and,
2. the reduction of prescriptive and directive communication in school in favour of more narration and description.

The first Australian Course for General Science was drafted in Malaya by Frederick Daniel[4], a student of Lauwerys in the early thirties. The manuscript was published first as a series of texts which had wide use in Asia and Africa—*General Science for Colonial Schools* (Daniel, 1941/1960). An element of Lauwerys' argument for biology in general science courses lay certain economic imperatives which connected the profits to be derived from development of colonial agriculture and health to scientific manpower planning in Britain. In the colonies including Australia, the economic arguments more directly favoured General Science. Daniel quoted the Director of Education in the Federated Malay States in support of his General Science Course which had been "devised as a practical contribution (within the existing fabric of English education) towards the solution of the problem of productive labour" (p. 13)

> There can be no doubt that the bulk of the inhabitants must turn to agriculture and other industries, and that the Education Department will have to equip them for those paths of life. Any ideal of education, not adjusted to local wants, must lead to economic dislocation and social unrest. (Director of Education. Federated Malay States cited in Daniel, 1936, p. 13)

Daniel and Lauwerys considered that General Science textbooks should describe and explain in some detail the practical application of the general principles they deal with and endeavour to base their instruction on the native interests of children. These native interests were assumed by Lauwerys and Daniel to lie in the economic and technical careers that faced students rather than the cultural realm. Lauwerys argued, and Daniel's experience suggested, that instruction should start from the sort of question which these pupils themselves ask, rather than from what are logically the first principles of the subject. But questions about practical applications were often not forthcoming.

In reviewing the problems of his General Science program for the Colonial Education Service, Daniel wrote as a missionary for science, but pointed to the weaknesses in relying on a laboratory method in the colonies to "revolutionise the mental outlook of the local boy." "We shall have to catch them young and encourage an intelligent curiosity in their surroundings if we are to foster the true scientific spirit" (Daniel, 1936, p. 13).

The authors of General Science texts were still required to transmit the logical first principles of the academic examiners, and Daniel's Course did produce the examination results that were the basic currency of the exported English public examination system in Malaya and Australia. Indeed, his own students were so successful in the English that in 1947 he was later asked to write the *Detailed General Science Syllabus for the University of Cambridge Local Examination Syndicate*, for mainly overseas students studying for the English Certificate of Secondary Education. However, ambitious pupils and the teachers in the Colonies knew that they were ultimately to be judged on their ability to demonstrate a hold on those logical first principles which were the psychological and historical end-point of a prolonged pedagogical and institutional instruction in English grammar schools. This meant that no matter how successful it was demonstrated to be in the "Dominions," neither Daniel's texts nor the adaptation written by Daniel and Turner (1943 and 1946), *General Science for Australian Schools* could never be recognised in the ultimate sense that they would have liked of being adopted in English grammar schools.

General Science was an adaptable vehicle in Malaya and Australia where it was not a metaphor for lower class schooling in science. This was the fate of General science in the Norwood Report where it became the prescribed course for students in the secondary modern schools after 1944. Lauwerys and Daniel saw the modern science text for all students beginning with the science of everyday experience: topics like "the growth of seeds," "the food of animals," "the functioning of hot water systems," and "the working of aeroplanes and motor-cars"; whilst, in contrast, the older books started, they observed, at one logical level removed: "the anatomy of flowers," "unicellular organism," "the measurement of temperature and coefficients of expansion, or the principles of levers." Whilst it would be true to say that in neither Lauwery's nor Daniel's arguments was there an explicit notion of intellectual development, they were grounded in the motives of natural curiosity and social utility, which can be readily related to the first two of Nunn (1920) and Whitehead's (1922) three phases of educational development.

The essential methodological problem facing those who urged a primary commitment to the illumination of student experience in daily life was, as Dewey (1938) observed, "to select and treat those experiences in a way which would bear fruit in future education" (p. 123). If liberal education did change to encompass broader social aims, then the problem of content selection was multiplied. Whilst Lauwerys felt that the issue had not been faced in England, he, Daniel, and Turner were confident that practical solutions to the problem of continuity and preparation for further study could be found as long as the separate disciplines could still be recognised in the syllabi. The problem of sequence was a problem for the textbook writers. Lauwerys and Daniel saw the need to take account of the interests of children and adolescents in both choice of content and sequence. For Turner, the young Professor of Botany at the University of Melbourne and Chairman of the first General Science Standing Committee in Australia, responsible for imposing a compulsory general science on all teachers, the problem of sequence and method had been satisfactorily "settled" in the relatively open narrative form by Daniel's manuscripts. Forty years later, Turner emphasised in interviews with the author, that he admired particularly Daniel's editorial rule of thumb that, if a term appears in the text fewer than six times in a chapter then it should be excluded as jargon. Turner added a glossary of scientific terms to each chapter of their text.

Whilst Turner encountered public opposition to content excisions and timetable allocations in the new examination course from the departments of Chemistry and Physics at the University of Melbourne, and from the senior teachers in the private schools, little or no attention was paid in discussions to the presentation of the public or political nature of Science. Lauwerys and Daniel understood that textbook organisation could be taken to define logical possibilities or necessity and, further, that what was presented as a logical relationship in the text passed as rigorous science if students found it difficult on exam papers. Lauwerys saw that what the school text characteristically took least seriously was the question of method, either scientific or pedagogical, or the fusion of the two. As he put it, "the form of the text prescribes and defines truth." He saw it did this, "not only in generalisation and theory," it selects and simplifies" but "also by what it excludes"(p. 445) Most noticeably, it excluded the possibility of knowledge in the process of becoming. "Knowledge," he observed, "is presented fully armed, present, and bound in a concrete structure of technical meaning and relations" (Lauwerys, 1940, p. 446). Lauwerys, Daniel and Turner believed that a good textbook and examination paper could be effective instruments of classroom reform .

Fostering the Scientific Attitude—To Present the Fallibilistic View of Scientific Knowledge

Daniel and Turner's texts included a number of carefully illustrated laboratory investigations. An appreciation of "the scientific method" was to Lauwerys and Daniel a third component of the General Science concept and as important as the other two: the introduction of biology and the classroom narrative of everyday science. However, the General Science course was to foster the scientific attitude or spirit—a passion for new knowledge and truth—rather than Armstrong's (1925, p. 10) "training of the faculties of thoughtfulness and power of seeing: accuracy of thought, of word and deed" in laboratory based exercises. Different Herbartian perceptions of learning which accommodated the developing child gained influence; theories such as Nunn's three phases of education, encouraged a broader view of teaching method and the introduction of new subject matter. In particular Armstrong's exclusion of Biology on the grounds that it provided a less satisfactory "mental training" because it was less amenable to precise measurement, and was "inferior from an experimental point of view" was less tenable. Jenkins (1979, p. 67) observed that, Armstrong's heurism also had important ideological features. Scientific knowledge was seen as neutral, objective and value free so that science as a practice could claim a special, even uniquely infallible place among human activities. Lauwerys sought to emphasise humanitarian values in

Science attributing the loss of popularity of the heuristic method to Armstrong's failure to accommodate or appreciate the powerful social claims of scientific knowledge on school science courses and his naive view of scientific method and its transferability. Lauwerys after Nunn and Dewey put each learner in the position of an original investigator. In so doing, Lauwerys emphasised the intellectually active role of the student in class. "We should force each learner to state the questions he is looking into, and force him to find out answers for himself in doing experiments" (Lauwerys, 1940, p. 449). Lauwerys was nevertheless concerned here to redefine, through the association with Armstrong, the conventional argument for the disciplinary as well as the utilitarian and cultural function of school science. In his view of the wider educational uses of Science in the new secondary school, he emphasised "the improved understanding of the nature of Science that the boys would acquire while their judgment and independence would be strengthened" (Lauwerys, 1940, p. 448).

Whilst Lauwerys argued that General Science was concerned with "the student's ability to find and use fact," he was aware that textbook communication was predominantly in generalisations and theory, and any commonsense testing that went on in science classes would tend not to be verbally formulated. Lauwerys was prepared to go further than Turner in attacking "the crude, clumsy and primitive ways of measuring knowledge ascribed to by public examinations." Turner, included in his sample general science examinations questions which called upon students to offer scientific explanations for common phenomena such as the fogging of a dentist's mirror, attempt descriptions of simple scientific experiments to test certain simple ideas, and to interpret secondhand data (Turner, 1943). He came to feel that he needed to provide for two types of student in a General Science programme, the career-oriented students who could be taught and assessed on their hold on mathematical principles and definitions, and the majority, who should be assessed primarily on their practical interest in natural phenomena. Turner like Daniel was more cautious than Lauwerys about the possibility of fostering in the fifteen year olds studying general Science "scientific habits of mind" and an appreciation of the "wide applicability of the scientific approach to ordinary concerns of life." Lauwerys quoted Bernal to emphasise the point of distinction from Armstrong's laboratory method: "Training in school science must give a practical understanding of scientific method, sufficient to be applicable to the problems which the citizen has to face in his individual and social life" (Bernal, 1939, p. 45).

The Problem Method—The Primacy of the Intellectual Method

Turner, the experimental plant physiologist, was less than impressed by the practicability of the notion of training young students in a "scientific method." He recommended what Lauwerys described as the "problem method" in his preamble to the first Australian syllabus. Lauwerys advocated the pragmatic approach of Nunn, Whitehead and Dewey to foregrounding the social context in which learning was to be intellectually framed.

> Teachers practising the problem method no longer present the pupils with, say, lessons on Boyle's Law: that is, I'll tell you what to think and then we'll do some numerical examples; then we'll verify the Law experimentally, and then you'll write it all up. Instead, such a lesson arises incidentally out of a consideration of things like bicycle pumps or barometers. At some point in the development of the topic comes the question, "Is there any relation, between the volume occupied by a gas and the pressure it exerts? (Lauwerys, 1940, p. 447)

A psychological-inductive approach rather than a didactic-deductive approach was advocated by Lauwerys in which the students themselves were to formulate their own understanding and were helped to express this in the form of abstracted laws. Daniel and Turner's (1943, p. 6) concern was that students should understand the scientific principles in operation in their everyday lives.

Whether they came from school science to appreciate the practical example, or from the practical example to appreciate the science seemed to them to be irrelevant. For Daniel and Turner, a good text would describe examples and principles; the teacher and pupils could relate them in both ways. Lauwerys saw the value pupils derived from the problem method in terms of what they learned about the scientific way of looking at social problems and of tackling them. Daniel and Turner, on the other hand, sought student understanding of scientific principles and applications in their everyday lives. They advanced no formal mental training .

"Problem solving," was the image of the preferred scientific teaching method substituted for Armstrong's "heuristic" method to broaden the historical and cultural compass of Science teaching. The same Archimedes' Principle was to be taught not as a "property of fluids" or as a method of determining specific gravity but as the principle which explained why boats were able to float.

In this pragmatic argument, the theoretical edifice of scientific thought and the strength of general science rested neither on the empirical piles of objective science driven from above through the marsh into a rock bottom nor a chain of rustproof concepts but is rather extended in a thread spun by twisting fibre on fibre and the strength is in the overlapping of many fibres.

Turner described the function of practical work in the Melbourne University Schools Board (1943/67) requirements as being simply to ensure that there be some legislated break from lifeless teaching in the science classroom. It was not that students or teachers should practise science in any significant sense: the practical work regulations were as much directed to the edification of teachers, and forcing a commitment from private school headmasters and the Education Department to improving the environment of science teaching through the construction of laboratories and the appointment of academically qualified science teachers (Fawns, 1988, p. 95).

Teaching for Social Transfer—The Representative Character of Thinking

It had been a familiar convention from at least the 1880's to deal in some detail with the chemical classification of substances into acids, bases and salts, and into elements, compounds and mixtures. Lauwerys argued that in General Science it is necessary that when the purely chemical part of such work is completed, there should be some discussion of the general principles of classification in other areas of science. He had in mind the need to point out that objects placed in a class must have something in common, and that they must have some property or other which distinguishes them from objects left outside the class. The teacher should, he suggested, point out that many different classifications of the same objects are usually possible, and that this means that there is nothing absolute about classifications: "They are manmade inventions which help us to think straight about things" (Lauwerys, 1940, p. 447). Lauwerys suggested further that it would be valuable to show students that it is often difficult to know into what category to place any particular object so that some degree of arbitrariness is always involved. Classifications by form or by descent could, however, be shown to be more significant than classification by weight or height in biology. The teacher, Lauwerys felt, would by such a discussion have succeeded in making plain to his more intelligent pupils what the principles of scientific classification are. The knowledge at first was embedded in a chemical matrix. He would have freed it from this and shown that the class work had a much wider application .

Moving from the laboratory to the application of the principles to new fields, Lauwerys could see pupils being asked "to classify the advertisements in a week's issue of a newspaper according to size, subject and psychological appeal" (p. 447). Better still, Lauwerys felt their "attention might be drawn to Hitler's division of mankind into Nordics, Aryans No. 1, Aryans No. 2, Mediterraneans, Jews, Sub-men, Semi-apes, etc " (Lauwerys, 1940, p. 448). He suggested students might be asked to consider how far it met the principles of scientific classification, what degree of arbitrariness in the definition it entailed, what can be concluded from it, and what purposes it is intended to serve. Lauwerys concluded, drawing support again from Bernal,

> To develop a scientific outlook in the pupils with regard to everyday affairs is a more worthy and socially important goal than to stuff them with facts. Is not Science, now as always, man's chief defence against superstition and barbarism? Do not the Nazis themselves recognise its power by persecuting it and its followers unless they renounce what is essential to its spirit by joining in the worship of the State idols? (Bernal, 1939, cited in Lauwerys, 1940, p. 448)

Liberal democratic arguments for public education in logic or "clear thinking" to counter extreme political ideologies and false advertising became the province of other subjects in the war years leading in the direction of education for citizenship in both England and Australia. Propositions like those of Lauwerys, more mainstream in American education, appeared in the thirties in the preface to books, such as Thouless (1938) *Straight and Crooked Thinking*. Later, Thouless' and Jepson's (1936) treatment (Fawns, 1987) of the "scientific method" became texts for "Clear Thinking," a formal invention of the reformed English subject syllabus, as it moved the focus of English language teaching from literature to "English Expression" at senior school level after the war.

Planning the General Science Syllabus

The SMA's General Science Committee found that the proposition they advanced, in the Final Report (SMA, 1938) which adhered to the traditional academic form, was more likely to secure the support needed in the English public schools and to secure the expanded time allocation on the timetable to teach the enlarged agenda. The Interim Report with its proposal for a single subject General Science which integrated the three areas was initially welcomed in England and Australia by the old humanist principals in public schools who were keen to protect the classical form of the literary curriculum against the expanding demands of the sciences.

Lauwerys struggled unsuccessfully to reconcile the various political necessities of his ideals. He criticised schemes such as those devised by a teacher unionist, H. S. Shelton (1939), who proposed topic divisions such as water, air, acids and alkalis, machines, evolution, wave motion, radioactivity, and the atoms. Lauwerys, felt they foregrounded the academic and theoretical. They also included little biology. Shelton argued that these topics were preferred by students because they dealt with science that, after Herbert Spencer, "everyone living in a modern scientific society must know," and could also be related to conventional subdivisions of science. The professionalisation of science teaching, Shelton felt, was bound to the chariot wheels of academic specialisation.

In a highly favourable review of Daniel's *General Science for Colonial Schools*, Lauwerys made a similar criticism of the course that he regarded as "amongst the best, and certainly the most carefully prepared and fully tested":

> As I studied this course, I wonder whether it had not been unduly influenced by the traditional approach enlivened in examinations. Is it necessary to group together for teaching purposes facts that are chemical, facts that are botanical, facts that are physical? ... The usual theoretical division has one enormous drawback: it makes it difficult to exhibit to beginners the social relations of science—the way in which human life and the structure of society has been shaped and modified by the advance of knowledge. Merely to add to orthodox lessons a short description of practical applications is not enough to achieve this aim. What is needed is a treatment which will train people habitually to think of science in terms of human welfare. (Lauwerys, 1941, p. 102)

Here, as elsewhere, Lauwerys restated his commitment to Lancelot Hogben's social criterion in his enormously popular *Science for the Citizen.*

> A course in General Science designed to meet the needs of citizenship must reinstate confidence in the human reason, reinforce constructive social effort and give the citizens of tomorrow a vision of what human life could be if the treasury of scientific knowledge were dedicated to the satisfaction of common human needs. If it is to do this, we must lay aside our preoccupations as specialists and find a common ground of agreement in our common needs as citizens. (Hogben, 1939, cited in Lauwerys, 1939, p. 35)

> Lauwerys felt that the "unit plan" developed in the USA attempted to meet this challenge and was the best scheme. There, he observed, the syllabus is arranged under headings such as "How does man obtain and control the energy of fuels? How are our homes provided with an adequate water supply? How does man construct his buildings? How does man provide transportation?" (Lauwerys, 1940, p. 448)

> Each of these units deals with material which is of great importance either to individuals or to communities. The facts dealt with belong together since they are all needed for the solution of problems, the importance of which is obvious to everybody. But the criterion of "belonging together" is a social one, and not a logical one. (Lauwerys, 1941, p. 104)

Shelton had no sympathy for American attempts to popularise science teaching.

> The necessity to cater for popularity certainly gave a stimulus to the development of a new type of teaching; but a course designed to meet such a need is naturally lacking in educational value. Where the school and teacher are urged to "sell" the subject to the pupil, and to the parents, it is hardly to be expected that due appreciation will be given to logical order, or to the proper understanding of the principles of science. Some critics have described these courses as general but not science. Emphasis is laid on environment without any very clear definition or understanding of what is meant by environment. (Shelton, 1939, pp. 13-14)

Shelton, wanted topics that science teachers could teach in a syllabus pictured conventionally as a chain of thinking. He saw Lauwerys' thematic Unit Plan simply as a loose type of topic scheme, whereas Lauwerys sought, but did not find, a new metaphor for thinking, for classifying similarities pertinent to modern science. After six years of debate in England, Lauwerys' inability to materialise his socially situated reforms in a system designed for pre-professional training was matched by Shelton's inability to articulate the broad cultural and political relevance of his "necessary" system. Lauwerys spoke for a school science that he hoped would be an essential humanity, a humanising force in the grammar school, while Shelton (1948) wrote for science teachers in the secondary modern schools. Lauwerys drew on liberal pragmatic notions (Sheffler, 1988) of a more dialogical and historic perception of science in vogue in the New Education Fellowship (Cunningham, 1938). His purposive, organismic, functional view of the learner and a fallibilistic view of scientific knowledge foregrounded the social context. Turner, unlike the other figures, had the authority to mandate his proposals for an Australian General Science for all students in all schools in Victoria. Daniel and Turner's extended response to Lauwerys' criticism of Daniel's course structure is preserved in the preface to *General Science for Australian Schools.* The response, which defined their view of the possible at that time, began:

> The ultimate ideal is the evolution of a General Science Course arranged in unity around central topics, where the unifying principle is the social relations of science. But we must learn to walk before we run and we believe that the present course will provide most schools with a sufficiently big step in the right direction. (Daniel & Turner, 1943, p. 3)

Discussion

Lauwerys, Hogben and a few civic minded scientists, before and during the 1939-45 war, in England and in Australia, attempted to educate the public towards a public interest contract between science and government. They sought to induct school students into a broader citizenship of science than that of the academic community. However, as Layton reveals, the central and enduring concern of the British Association (Layton, 1981) and the Science Masters' Association (Layton, 1984) has been the production and nurture of the scientific seed corn, and specifically the shaping of the secondary school science curriculum to serve their shared scientific (Fensham, 1993) and professional ends in the key educational task of reproducing a technical class.

Despite the virtual eclipse of faculty psychology and the heuristic method of teaching science by the twenties, some of Armstrong's ideas continued to influence school science through writers like Lauwerys. An emphasis on practical experimental teaching and a belief in the importance of learning by doing became established features of the discourse of reform. Resolution of the paradox posed by Armstrong's conception of scientific method ultimately resides in a recognition that the logical and imaginative operations of science are conducted with what Ravetz (1971) and many others currently see as "intellectually constructed things and events" and not with "objects of commonsense experience." Although these intellectual constructs of science are designed to relate as closely as possible to the inaccessible reality of the external world, they are not, as Armstrong's heuristic and Huxley's "organised common sense" seemed to imply, identical to it. It follows that some aspects of scientific method cannot readily be taught and that an appreciation of the methodology of science requires that students be introduced to these intellectually constructed "things and events." Hence as heurism lost its philosophical and psychological support, the stage was set in the thirties for a reassessment of the contribution of natural science to liberal education and for a renewed emphasis on the acquisition of scientific knowledge as an educational objective in the arguments for a general science for all in England and later Australia from the thirties.

All parties to the debate, concerned about the balancing competing needs for academic training and social education through science education, before and during the war felt that the public interest demanded an extension of science education starting with an expansion of the timetable allocation in English public schools to a broader public. Scientific knowledge narrowly or broadly defined challenged entrenched and powerful literary, linguistic and grammatical traditions in private schools in particular. Teachers of school chemistry and physics in these elite schools opposed any General Science syllabus which threatened to limit or even reduce their timetable allocation while adding biology. This debate led directly to the formation of the Science Teachers Association of Victoria in 1943 (Fawns, 1988a). Lauwerys came under attack for example from expert specialist teachers of chemistry and physics who saw him as an outsider who did not recognise their professional achievements and the fine traditions of English science teaching that he sought to reform.

> Although I agree with much that Mr. Lauwerys has written, I cannot but regret that, in commentary on science teaching as at present practised, he should darken counsel with his inexperience and his inaccuracies. If his gibes and glancing remarks on modern teaching are true, many things that should have stirred them have passed over science teachers' heads, leaving them unmoved: for example, the prolonged and penetrating, if at times truculent, criticism of Professor H. E. Armstrong, the more sweetly reasonable persuasion of Professor Smithells, the efforts of Alexander Smith to improve the teaching of chemistry, the 1919 report, *Natural Science in Education,* the help that splendid quarterly, *The School Science Review*, and the many conferences of science masters. Assuredly Mr Lauwerys' ideas of the state of chemistry teaching seem to be thirty to fifty years behind the times. (Fowles, 1939, p. 145)

Academic subjects have, Goodson (1990, p. 404) observed, provided the social esteem and career structure characterised by better promotion prospects, resource allocations and pay than less academic subjects. Lauwerys and those academic educationists who argued for the social relations of science in General Science and Biology were often outsiders to the established subcultures of school Physics and Chemistry. In Australia, more so than in England, Gregory's (1916) plea for reform of school science teaching, "much more of the spirit and less of the valley of dry bones," (p. 36) was associated closely in the general science debates with the argument to introduce school biology. By the thirties there were calls to reform pre-university studies in the biological sciences in England and Australia in the thirties. Some reformers argued for a greater emphasis on social biology on one hand and others for laboratory based disciplines on the other. Both were concerned to replace the emphasis on the morphology and physiology designed as pre-medical courses in schools (Fawns, 1988b). The Social Relations of Science movement in the British and Australian Associations for the Advancement of Science was as Werskey (1971) and Macleod (1988) show neither monolithic nor cohesive and involved few members in the scientific community. The fundamental division within the movement was between reformers like Gregory, Polanyi and Julian Huxley, who sought to raise the prestige of and support for scientific research particularly in the biological sciences, and socialists like Bernal, Hogben, Haldane and Needham who argued that the fullest and most humane use of science was possible only in a society reorganised along socialist lines. Lauwerys spoke at British Association meetings in support of the radical agenda. In war service they all worked together but once the war ended, the gradual improvement in the status and funding of scientific research satisfied many of the reformers who were content to be called upon to advise on policy rather than to formulate it. Werskey (1971, p. 246) suggests that the radicals channelled their efforts into the Federation of Scientific Workers and the Campaign for Nuclear Disarmament.

In Australia, the newly appointed academic botanists, mainly English and Cambridge educated, like Wadham and Turner in Victoria, Wood in South Australia and Ashby and Robertson in New South Wales, and the much older Dakin (1918) in Zoology, were all concerned with their neglected science and the small numbers of boys enrolled in the biological sciences beyond the first exam level. During the war Ashby and Turner became the first chairmen of their state branches of the Australian Association of Scientific Workers and spoke at these gatherings about general science education in schools. They found field work studies, in the British tradition, was a neglected in Australian secondary schools. For Turner in particular the narrative of the botanical ramble captured the spirit and the purpose of their scientific enterprise, as well if not better than displays of laboratory equipment. To them the General Science text, too, could be a more discursive narrative, elaborating the broader aesthetic and social as well as the technical satisfactions to be gained in learning science. John Turner was beholden to a similar landscape vision that General Science could provide a liberal education by the study of nature, "the sight and history of men and the setting forth of noble objects of action" (J. Ruskin. cited in Jenkins, 1979, p. 57). For Turner, like Ruskin, there was a vision of a just society achieved through cultural change. For Turner in his new country the cultural change he sought was towards nature conservation.

Conclusion

The pragmatic representations here of the General Science network of Lauwerys, Shelton and Daniel and Turner were constructed at the intersection between themselves as persons and society as they dealt with it prior to and during the 1939-45 war. The interpretation is grounded existentially in understanding their discursive action. The notions such as "general science," "liberal education," "the scientific method," "broadening the syllabus" and "the reforming text" cannot be taken as timeless entities with fixed meanings, but as weapons after Heidegger (1962) or tools after Wittgenstein (1958), the understanding of which was always a matter of seeing who is wielding them and for what purposes. The intensification of conflict over the social function of science teaching, either for an education for informed citizenship through general science or for recruitment and training into the specialist sciences, in this period led directly to the formation of science teacher associations in four states in Australia in the forties. The personal narratives and the history are intimately related throughout. This can be illustrated in a brief biographical denouement.

John Turner, whilst engaged in his PhD research at Cambridge in 1936-37, had been a member of a radical circle aligned with the Association of Scientific Workers which supported Haldane and Bernal's call for democratic accountability of science. Turner and an Australian, Rutherford Robertson, were but two of the young scientists at Cambridge exposed to the activities of the British Association of Scientific Workers and the Cambridge Scientists' Anti-War Group (CSAWG). In a calculated risk, the Home Office issued a document called, "The Protection of Your Home Against Air Raids," which told the population how to prepare a refuge room against the entry of gas. "Fill in all cracks and crevices with putty or a pulp made of sodden newspaper. Paste paper over any cracks in the walls and ceilings" (Turner, 1984 taped interview). Turner put this nonsense to scientific test. He applied his research apparatus, which was designed for accurate measurement of respiration rates in plant tissue by detecting small changes in carbon dioxide concentrations. He measured rates of gaseous diffusion through the walls of a room lined by his group with newspaper in the manner prescribed by the Home Office. The results were widely reported in the national press and brought a hostile reaction in the British Parliament to the CSAWG's experimental testing and repudiation of the Government's Air Raid Precautions Provisions which had been prepared without adequate scientific consultation.

The key issues were the scientific illiteracy of government and the citizenry and who benefits. This was accounted in a pamphlet of the day written by J. B. S. Haldane,

> If science is to advance in this country as it should, we need more democracy in the laboratories, and also more democratic control of expenditure on research. This will only be possible if the people are educated in science, and they are at present deliberately kept in the dark. For a knowledge of science leads to realisation of the huge amount of knowledge which could be applied to public benefit if industry, agriculture and transport were organised for use and not for profit. And knowledge of this kind is dangerous to capitalism." (Haldane, 1939, p. 7)

Turner and Ashby were academic humanists who considered themselves to be less doctrinaire socialists than Haldane. However they also deplored the uses of science in support of individualism, phenomenalism, sensationalism, and materialism, in favour of a conception of science that would in contrast be "realistic," that is, would emphasise the abstract, the general, and the social. We can learn from their method but critically by asking when and why General Science became defined as an issue at certain times and in certain places in England and in the various Australian states, we can call attention to underlying structural issues in the social relations of the professional organisation of science and science teaching. This in turn helps us to understand our own agency and structuration in our urgent attempts to revitalise general science, to at least determine a more effective policy than accepting current economic terms of debate as controlling. Understanding our agency requires a suspicion of overarching theories and singular schemes of explanation. Silver (1983), Goodson (1990), Fawns (1996) and Kliebard (1986) have observed, curriculum schemata, ideologies and opinions do not float in space; they arise from particular social strata, serve particular groups and interests, and change over time as the relations of people change. As reform movements they also persist. General science education in the period studied, and again in the Apollo mission period, was revitalised by the "spirit of science abroad in the world."

The proponents of general science in each period heralded the growth of scientific intelligence and its application to the problems of the human condition. Through their critical review of the inherited concepts of nature and practice in science and school science they set the stage for different conditions of social life.

Like sailors who must rebuild their ship on the open sea, they and we are never able to dismantle scientific thought and education in dry-dock and to reconstruct it there out of the best materials. We must stay afloat, repairing any part of the ship that springs a leak by using material from the rest of the boat, relying on the rest to keep us afloat during the process of repair. The process may be continued without end, yet nowhere is there the possibility of rebuilding afresh.

Notes

1. Joseph Lawerys was a lecturer in Science Method at the University of London's Institute of Education at the time of this work on the popularisation of General Science amongst teachers in particular. See Lauwerys (1937). He was the principal author of the Science Masters Association's *Interim Report on General Science: Part I (1936) and Part II (1938)* which were probably the most widely read statements of the principles and rationale of General Science. He was an advocate of biology teaching in secondary schools, see *Education and Biology* (1934). He spoke with other distinguished progressive educators at the widely reported World Congress of the New Education Fellowship in Melbourne, Adelaide and elsewhere in 1937. Proceedings in Cunningham, K. (1938). He was later active on the Council for Curriculum reform and edited at least one report for them. See Lauwerys (1945). He became Professor of Comparative Education at the Institute.

2. J. S. Turner, Professor of Botany and Plant Physiology at Melbourne University 1938-74 — conservationist and public educator. See Ashton & Ducker (1993). Turner was an emblematic figure in the post war development of secondary science education in Australia. He was the Chairman of the General Science Standing Committee of the Schools Board for 25 years controlling both syllabus and examinations to the year 10 level. He coauthored the first general science text and introduced a new science degree to better prepare science teachers for general science teaching. In this period all Australian states adopted a General Science to replace specialist science subjects at the first examination level. In 1945 he introduced Biology as a senior school subject in Victoria replacing Botany and Zoology. He chaired the Biology Standing Committee for 30 years culminating in the production, through the Australian Academy of Science, of *The Web of Life* (Morgan, 1967) course structured after the American BSCS texts but completely rewritten, that completely reconceived the purpose, structure and function of biology teaching in Australia. It transformed the public image and status of biology as an experimental science. It became effectively the national course for twenty years. Turner was the first President of the Science Teachers' Association of Victoria and the inaugural chairman of the Victorian Branch of the Australian Association of Scientific Workers at the first meeting in 1940 of which, he reported that fewer than 200 boys in any year studied any biological subject at year 10 or beyond. He was similarly involved in the formation of key nature conservation bodies in Australia. (See Ashton & Ducker above) An analysis of Turner's agency and networking in education, his public campaigns, personal correspondence and interviews in Fawns (1988).

3. H. S. Shelton was probably the most prominent teacher voice on the General Science question in this period. In Shelton (1939) he was critical of the syllabus of the SMA and offered an alternative "rational scheme" of work based, not upon "the technology of the specialist sciences" but upon "what ought to be familiar to the ordinary educated man." Shelton expressed his views in a variety of articles in *The School Science Review, The Schoolmaster and Woman Teacher's Chronicle.* His first scheme for General Science in a six page supplement to the Chronicle, Nov 7, 1935. He stated his commitment to the essential unity of knowledge in utility as professed by the social Darwinist Herbert Spencer. He argued for a science topic approach rather than a social thematic approach. A topic, pictured as a link in a syllabus chain, was "some thing or substance which is common in the world and well known to the child before the Course begins." His topics subdivided into Physical Science (6 periods/wk) and Biology (2 periods/wk) included "water," "sulphur," "metals," "machines," "wave motion," "evolution." His general science textbook, Shelton (1948) was written for Secondary Modern Schools.

4. Frederick Daniel was a student of Lauwerys at the London Institute. He was a science expert employed in the Malayan Educational Service of the Colonial Office. He wrote *General Science For Colonial Schools* (1938) in 4 volumes and *General Science for Tropical Schools* (1941) which together with his companion series of work books sold over half a million copies. Also *Health Science and Physiology for Tropical Schools* also for OUP. During a visit to Melbourne in 1940 in which he brought his manuscript for the 4 volume text to Frank Eyre at OUP he was introduced to John Turner and they collaborated in adapting it into the 2 volume *General Science for Australian Schools* (1943/6) for the new General Science Subject at years 9 &10 level. This was the first Australian text in general science. Daniel was interred during the war in Singapore. The extended poignant correspondence to 1960, between the Daniel and Turner is preserved in the Turner Files at the University of Melbourne Archives.

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References

Andrade, E., & Huxley, J. (1934). *An introduction to science.* London: Blackwell.

Armstrong, H. (1925). Training in scientific method as a central motive in elementary schools. In G. Van Pragh (Ed.). (1973). *Armstrong and science education* (pp. 15-32). London: Routledge.

Ashby, E. (1939). Report of meeting establishing the Australian Association of Scientific Workers. *Australian Journal of Science, 2*(3), 94.

Ashby, E. (1942). Science and social reconstruction. *Australian Journal of Science, 5*(4), 4.

Ashby, E. (1947). *Scientist in Russia.* London: Pelican.

Ashton, D., & Ducker, S. (1993). John Stewart Turner 1908-91. *Historical Records of Australian Science, 9*(3) 1-26.

Bernal, J. (1939). *The social function of science.* London: Routledge.

Bibby, C. (1971). *T. H. Huxley on education.* London: Cambridge University Press.

Cunningham, K. (1937). *Report of the committee on secondary education in Victoria.* Melbourne: Australian Council for Educational Research.

Cunningham, K. (Ed). (1938). *Education for complete living*. Melbourne: ACER.

Dakin, W. (1918). *Elements of animal biology*. London: Macmillan.

Daniel, F. (1936). The general science course in the Federated Malay States. *Overseas Education, 8*(3), 157-60.

Daniel, F. (1938) *General Science for Colonial Schools*. London: Oxford University Press.

Daniel, F., & Turner, J. (1943/6). *General science for Australian schools*. Melbourne: Oxford University Press.

Dewey, J. (1938). *Experience and education*. New York: Macmillan.

Fawns, R. (1987). Clear thinking and scientific method for our future leaders. *Research in Science Education, 17*, 67-77.

Fawns, R. (1988a). *The maintenance and transformation of school science*. Unpublished PhD thesis, Monash University, Melbourne.

Fawns, R. (1988b). The cultural roots of school biology in Australia—From vitalism to dialectical materialism. *Research in Science Education, 17*, 67-78.

Fawns, R. (1991). Stories tell but words conceal—Aspects of historiographical research. *Research in Science Education, 21*, 74-82.

Fawns, R. (1996). The struggle for general science in Australia: The final campaign in the technical schools in Victoria. *Research in Science Education. 26*(1), 1-22.

Fensham, P. (1993). Academic influence on school science curricula. *Journal of Curriculum Studies, 25*(1), 53-64.

Fowles, G. (1939). General science: A chemistry master's criticism. *New Era, 20*(6), 145-47.

Goodson, I. (1990). *School subjects and curriculum change*. London: Falmer Press.

Gregory, R. (1916). *Discovery or the spirit and service of science*. London: Oxford University Press.

Haldane, J. B. S. (1939). *Science and you (Key Books No. 1)*. London: Fore.

Hatfield, J. (1938). *An introduction to biology*. London: Oxford University Press.

Heidegger, M. (1962). *Being and time*. London: Oxford University Press.

Hogben, L. (1939). *Science for the citizen*. London: Routledge.

Holmes, B. (1981). *Joseph Lauwerys at the London Institute*. Libraries Bulletin Supplement 22, London Institute of Education.

Huxley, J. 1932). Biology and cultural view. *New Era, 13*(1), 6-10.

Jenkins, E. (1979). The general science movement. In E. Jenkins, *From Armstrong to Nuffield* (pp. 70-107). London: John Murray/ASE.

Jenkins, E. (1981) Science, sentimentalism or social control? The nature study movement in England and Wales 1899-1914. *History of Education, 10*(1),15-55.

Jepson, R. (1936-1965). *Clear thinking*. London: Longmans.

Kliebard, H. (1986). *The struggle for the American curriculum*. Boston: Routledge & Kegan Paul.

Lauwerys, J. (1937). General science. *School Science Review, 18*(72), 466-480.

Lauwerys, J. (1939). General science, a plea for its adoption. *New Era, 20*(3), 13-18.

Lauwerys, J (1940). General science now. *The Journal of Education, 72*(4), 446.

Lauwerys, J. (1940). Reply to Cunningham. *Journal of Education, 72*(5), 526.

Lauwerys, J. (1941). Review of general science for colonial schools (Books I & II). *Overseas Education, 12*(2), 101-4.

Layton, D. (1981). The schooling of science in England, 1854-1939. In R. Macleod, & D. Collins (Eds.), *The parliament of science* (pp. 75- 108). London: Science Review Ltd.

Layton, D. (1984). *The interpreters of science*. London: John Murray/ASE.

Lewis, C. (1938). *The abolition of man: Reflections on education with special reference to the teaching of English in the upper forms of schools*. London: Geoffrey Bles.

Macleod, R. (1988). *Commonwealth of science—ANZAAS*. Melbourne: Oxford University Press.

Medley, J. (1943). *Education and democracy*. Melbourne: Australian Council for Educational Research.

Melbourne University Schools Examination Board. (1943-60). Course of study for General Science in the *Handbook of courses of study and examination prescriptions*. Melbourne: Victorian Government Printer.

Moran, J. (1983). Rhetoric and representation in Australian science in the 1940's and 1980's. *Prometheus*, *1*(3), 9-17.

Morgan, D. (Ed.). (1967). *The Web of Life*. Canberra: Australian Academy of Science.

Norwood, C. (1943a). *Curriculum and examinations in secondary schools—Report of the committee of the secondary schools examination council.* London: HMSO.

Norwood, C. (1943b). Address to headmaster's conference quoted by Prof. G. Brown, Chairman of the MUSEB. In W. Ricketts (1944), *Gateway to science (Preface)*. Melbourne: Robertson & Mullins.

Nunn, T. (1920). *Education: Its data and first principles*. London: Arnold.

Phillips, M., & Cox, L. (1935). *The teaching of biology*. London: University of London Press.

Popper, K. 1945). *The open society and its enemies (Vol. II)*. London: Routledge.

Preese, J. (1950). *Personalities and power in english education.* London: Arnold.

Ravetz, J. (1971). *Scientific knowledge and its social problems.* London: Oxford University Press.

Reid, W. (1987). Curricula topics as institutional categories. In I. Goodson & S. Ball (Eds), *Defining the curriculum: Histories and ethnographies* (pp. 15-36). London: Falmer Press.

Scheffler, I. (1988). *Four pragmatists—A critical introduction to Pierce, James, Mead and Dewey.* New York: Routledge & Kegan Paul.

Science Masters Association. (1936). *The teaching of general science(Part I)* . London: Science Masters Association.

Shelton, H. (1940). Reply to J. S. Lauwery's general science and topics. *Journal of Education*, *72*(5), 524-525.

Shelton, H. (1939). *Theory and practice of general science*. London: Munby.

Shelton, H. (1948). *A textbook of general science*. London: Allman.

Silver, H. (1983). *Education as history*. London: Methuen.

Snow, C. 1959). *The two cultures and the scientific revolution.* London: Mentor.

Spencer White, A. (1938) *General science chemistry*. London: Dent.

Spens, R. (1938). *Report of the consultative committee on secondary education with special reference to government schools and technical high schools.* London: HMSO.

Thouless, R. (1938). *Straight and crooked thinking*. New York: European University Press.

Turner, J. (1940). Biology in schools; Report of a meeting of the Victorian Branch of the AASW. *Australian Journal of Science, 2*(3), 10.

Werskey, P. (1978). *The invisible college.* London: Allen Lane.

Westbury, I. (1983). School Textbooks. In I. Westbury (Ed). *The international encyclopaedia of education research and studies* (pp. 58-93). New York: Pergamon.

Whitehead, A. (1922). *The rhythm of education*. London: Arnold.

Wittgenstein, L. (1958). *Philosophical investigations*. London: Oxford University Press.