NYHOLM MEMORIAL LECTURE*

Forward from Nyholm's Marchon Lecture†

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In years to come it is certain that, whether they are concerned with chemical education or inorganic chemistry, these Nyholm Memorial lectures will become increasingly focused on what, at that particular time, is a current problem. I thought it appropriate therefore that in this first lecture, which it was decided should be a tribute from chemical education, there should be a greater concern with Ronald Nyholm's own impact on that activity and his place in it, particularly with the impact he made on it during the decade before his death. Yet at the same time I knew it would be no tribute to him to look back merely nostalgically or reminiscently. That would not be in keeping. I am sure he would have said that any looking back must be a deliberate part of a programme for moving on, and that is what I had in mind in deciding on the content of my lecture and is my excuse for the title's apparent flippancy.

There is no doubt that Ronald Nyholm was at the centre of great change and development both here and abroad, and in trying to get his influence into some kind of perspective I was helped by a comment recently made on the Nuffield Chemistry Project with which he was so intimately linked. The comment was that the project was not the beginning of a new era; it was the end of an old one. This I believe to be true – I also think it false. This paradox (which if substantiated would hardly endear itself to the setters of some of our modern examination questions) arises for me because I see many of the developments and chemistry teaching projects in those years (including the Nuffield Science Projects) as marking a watershed in science education. These various projects arose out of, and were predominantly based on, a past that had been increasingly active, but then, I think, they themselves, together with powerful, contemporary but extraneous social forces, resulted in the development of such new perspectives and contexts, and opened up such new possiblities that the period following them can be seen as qualitatively different. In this sense these science Teaching Projects, often cast in a mould appropriate to the earlier period, helped to catalyse the transition to a new period: they were both an end *and* a beginning.

That the decade from 1960 to 1970 marked a watershed for us in science

* Delivered at a Meeting of the Education Division of The Chemical Society on 10th April 1974 at University College, London.

† The 1964 Marchon Lecture was delivered by Professor R. S. Nyholm, D.Sc., F.R.I.C., F.R.S., at the University of Newcastle-upon-Tyne, 9th March 1964.

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education I see as a key perspective in future development: and I also see Ronald Nyholm as one of the outstanding men who by their efforts created the entry into a new era, a new era of which I know he was in fact beginning to get a glimpse. I therefore propose to develop this theme, and in doing so to put some of the new perspectives and contexts with which those going on will have to cope, into juxtaposition with the changes and developments of the past. In this Janus-like exercise let me start with a brief survey of that side of the watershed which was explored and developed by earlier generations and from which Ronald Nyholm and the rest of us started.

As a preliminary to this survey I would like to draw your attention to a remark of a social historian about a comparable situation. In his book, George Ewart Evans is commenting on changes in village life during the last hundred years. What I shall have to say is so much in keeping with his comments that I will quote them. He says this period is

> '. . . . a century to which science has given those innumerable skills and techniques that make the control of large sectors of our physical environment a reality; and – perhaps most important of all – has given us a confidence that falls short only of the awareness that now for the first time we are called not merely to suffer our own history but to make it. But make it on what? This question immediately points to a sense in which the study of the old, traditional culture is not simply a praiseworthy academic exercise but an essential preliminary to the building of a new order. For-------the old framework-------did house something permanent-------and without an appreciation of these (permanent characteristics) no attempt to make a new community here in Britain or elsewhere is likely to survive the present century'.[1]

So in the development of science curricula should we beware of the danger of regarding as outmoded the values and characteristics and the changes and developments of the past. Indeed we should carefully judge afresh the extent to which they are appropriate in a context that may be radically changed.

When we do look back on past changes one pattern at least stands out: the *recurrent* upsurging of progressive-type exhortations. It is indeed salutary to realize that some of the innovations which give us so much pleasure and which even provoke pride of achievement equally gave pleasure and were equally a source of pride to someone in our grandfather's and even in our great-grandfather's day. I strongly recommend to you the review of a century of science teaching which appeared in 1960 as the first chapter of 'Science in Secondary Schools',[2] issued by the Ministry of Education. It is brief and it is full of most enjoyable and encouraging detail, *e.g.* the work in science in the *village* school of King's Somborne in 1847 under the inspiration of the Rector, the Rev. Richard Dawes§ but for my purpose here, I am more concerned with the pattern,

§ An interesting view of the influence of Richard Dawes and other initiators in science education is to be found in D. Layton, 'Science for the People', George Allen and Unwin, London, 1973.

[1] G. E. Evans, 'The Pattern under the Plough', Faber and Faber, London, 1966, Introduction.

[2] 'Science in Secondary Schools', Ministry of Education Pamphlet No. 38, London, H.M.S.O., 1960, Chapter I.

which I see in its account, of a recurrent upsurging of new intentions over a period of a century and a quarter.

Before the middle of the past century science was a part of the educational experience of very few people: the few well-educated and interested adults influenced by the activities of the Royal Institution in London and by those of a few similar centres in educated circles elsewhere; a few pupils in schools such as Stonyhurst, Mill Hill, University College School, Harrow, Rugby, and others where the physical sciences were being taught before 1850; and a very few quite young school children such as those who, by chance, were influenced by such men as the Rev. Dawes in the village school at King's Somborne. Now when I say that I see this time as a period of the socially minded scholar, I am in no way pretending to an historical analysis but I am merely, in line with my theme, giving a cry of recognition of a phenomenon which, in a somewhat disguised form perhaps, we have seen held up for our approval in our own time. In a very general way we can see the major theme here as 'Know and Understand and Enjoy'. Indeed, in order to underline the structure of my theme, I hope I may be allowed to use mild slogans of this sort to pin-point the characteristics of these exhortations.

Then in the middle of the century a new social pattern burst into blossom, and the needs of a technological society and the importance, for the good economy of the state, of a scientifically literate work force, became the emphasis. Mechanics Institutes, established a decade or so earlier but which until then had shown rather weak growth on the science side, suddenly had support and encouragement. It was realized that in science education the French and the Germans were ahead of us, and this and the focal point offered by the Exhibition of 1851 seemed to have had the effect in the mid-nineteenth century that the Sputnik had in the mid-twentieth. In the same period and for related reasons two new factors appeared: the written examination, and the Revised Code of 1861 with its subsequent payment by results. The written examination did away with patronage and gave opportunity for selection by merit. One phrase used by Rev. J. Booth, one of its early protagonists, I particularly like. He referred to 'the reservoir of unbefriended talent'. But cries that we ourselves have heard in the last decade or so were soon heard then – nearly a century ago. Booth himself in 1861 was speaking of 'a general mania for examining everybody by means of written answers to printed questions', and Todhunter by 1873 was bothered that written examinations were becoming instruments of specialization. Kelvin told the Royal Commission on Scientific Instruction and the Advancement of Science (1872) that examinations exerted a 'fatally injurious tendency' on the higher parts of science, and Huxley in 1877 described competitive examinations as 'the educational abomination of desolation of the present day'. The second factor appearing at the same time as the large-scale emergence of written examinations was the Revised Code of 1861 which, by its formula of payment by results, led to primary schools (and hence training establishments) being, from then on for quite a while, concerned almost entirely with proficiency in the 3 R's. As the Ministry's own Pamphlet[2] comments a century later, 'a promising beginning

in the elementary schools (in science) was cut short' (by the Code).

The second stage, the aftermath of the Great Exhibition, cannot be looked back upon with any great affection. Its main theme, however, which can be characterized perhaps as 'Know and profitably Use', while so different from the 'Know and Understand and Enjoy' of the previous stage, is not fundamentally unacceptable: it was its implementation at that time that turned out to be so disastrously unimaginative.

Not surprisingly there was a revolt against it, a slow-moving revolt which was now fostered in the public and grammar schools. This revolt, by no means widespread but certainly influential, is associated with the work of Sanderson and particularly with that of Armstrong in the two decades bridging the turn of the century. In this, the principal drive was directed towards learning through experimental exploration followed by argument. The details of this heuristic method of science education are well documented, and an edited edition of some of Armstrong's essays has appeared recently.[3] I do not propose on this occasion to go further into details of this phase. Its later influence, after a period of eclipse, was considerable. What interests me here is that I can see in its characteristics a recurrence of the ideals of science teaching advocated by the Rev. Richard Dawes – now modified and strengthened by the tradition of mental training and character formation of the established schools for an adolescent group. I will use the phrase 'Know and be Educated' to indicate this movement.

Then came the First World War and a resurgence of the previous technological purpose and intention. The Ministry, in its Pamphlet,[2] speaks of the change as 'a swinging away of the emphasis *again* from method to the matter of the studies', (my italics) and I have spoken of the *recurrent* upsurgence of exhortation. Yet the resurgence of ideals was never just a repeat. Each stage had progressively left a mark on its successors. We see this particularly during the first thirty years of the present century. The work of Armstrong, of Sanderson, of numerous experienced teachers of physics and chemistry in the public schools was beginning to spread into the wider educational field of State Grammar Schools. The Association of Public Schools Science Masters expanded and became The Science Masters Association. Again, the first number of the School Science Review (June 1919) had an article on 'Research Work in Schools' and the sixth issue (December 1920) had an article on 'Science for All: a plea for General Science' – yet we have seen that this period following the First World War was not the first time that either the educational value of investigation or a doubt about the educational value of specialization had been the centre of discussion. But now there was a difference. Not only were many more pupils than in the previous century now involved, but in addition, education in the last decades of the nineteenth and the first two or three decades of the twentieth century was an instrument of social mobility – two facts that are not unrelated. The theme therefore for many, although not for all, in those years was 'Know and so get on – and out'.

[3] 'H. E. Armstrong and Science Education', ed. G. van Praagh, Murray, London, 1973.

I must repeat that what I am saying is in no way an attempt at historical analysis. It is just a statement of recognition that many of the slogans which in the last decade we have heard, or have even voiced, had during the last hundred and thirty years their earlier counterpart. Nor, I would hasten to stress, is what I have so far said a prologue to a jeremaid. The recurrent upsurging of progressive-type exhortations (there is an almost 'Old Faithful' regularity of thirty years interval) is not a repetition of despair, is not a fruitless, sisyphean repetition. Rather has each generation found that it in turn must cope with the needs and problems thrown up by its own idiosyncrasies and historical development.

When we look at the last three decades – so coming to the present time – we realize that the great expansion of the group of pupils and students concerned has resulted in such an inhomogeneity of ability and ambition that all the various, and even contradictory, slogans of the past may well now be appropriate to some sections of the group. Further it is now clear that the problems are not unique to us – they are international and the inhomogeneity of educational needs thus becomes even more marked. The development and elaboration of this international and multifaceted aspect of educational needs is indeed one of the characteristics of science education after the Second World War – the period in which Ronald Nyholm played so stimulating and so important a part both at home and abroad – and it is a characteristic of very considerable volume and complexity and one which is still awaiting a critical survey. I certainly have no intention here of offering even a sketch map of its ramifications for it is my purpose only to indicate generally the way affairs were leading up to, and were helping to bring about, a change which in retrospect I see as a watershed, and a change in which Nyholm played a vigorous and constructive part. At home and abroad this time has been a period of greatly increased activity and voluminous proposals. Not only was there, at home, a spontaneous upsurging of demands for a new look at science education, natural after another thirty years quiet, but North America and parts of Europe had felt the impact of what in educational terms can be regarded as the mid-twentieth century counterpart of that stimulus which the Great Exhibitions and outpourings of the first flowerings of the Industrial Revolution had given in the mid-nineteenth: countries were now 'sputniked' into support of science education. The first and important step was that administrations were sputniked into support but soon the educational activities, now with many more resources available to them, demonstrated their intrinsic worth, and, receiving calmer and more considered support, entered a vigorous phase of production and propagation. From the ideas of earlier years there developed and blossomed the American, the Scottish, the Nuffield, the Australian Schemes, first in chemistry, physics, and biology and then later in science in some integrated form. So too, but later, came schemes for South America, South East Asia, East and West Africa, schemes fed from the initiating schemes but sponsored and supported by such international organizations as U.N.E.S.C.O. and The British Council, with field support from the young people of the American Peace Corps and the British Voluntary Service Overseas. In

fact we witnessed what can be described as the twentieth century secular counterpart of the ninteenth century Christian missionary drive – there was even a faint suggestion of ill-defined salvation about it. Science education was an International Good Thing.

But in our home area we saw what at that time many thought to be an insurmountable obstacle to change. It arose from the establishment a century earlier of the written examination. This obstacle Nyholm showed was removable. Elsewhere[4] I have indicated how in the Nuffield Foundation's Chemistry Project Nyholm and the rest of us stressed very early that examination demands should be designed to assess and also encourage those intentions and aims which a particular innovation was striving to achieve. But by the middle of the twentieth century the pattern of examination demands (I mean what a candidate has to do in order to receive approval and achieve success) had, in the U.K., been fairly set for a long time. The fulminations of Huxley, of Todhunter, and of Rolleston ('men get demoralized by the process'), the opinions of Sir William Ramsay in the nineties that an ability to pass examinations might be a good qualification for a barrister or a government official, but not for a scientist (he needed developed inventive powers) – none of these fulminations in their own days had much effect. Nyholm's quiet but formidable administrative persistence was successful in his. As Moderator for the G.C.E. 'O' and 'A' level examinations in Chemistry of the University of London Examination Board he and his colleagues in the Nuffield Foundation were able to persuade the various Examination Boards to experiment with new types of papers without handicap to the candidates involved. I personally consider this achievement as one of Nyholm's most important in the area of educational reform. He reminded the rest of us that examinations were the servants of education and that a contrary approach had been allowed to grow up over many years and to have become established. He also showed in a practical way that examination systems were not unalterable modes of procedure. I also know he was very concerned that we should see we had carefully considered criteria thought out before we exercised the power to change. In this area of chemical education Ronald Nyholm was more of an outstanding and isolated figure than in others. Not of course that he ever was a lone figure. One's memory of him is that of a centre of activity in a group, fanning this section into flame or cooling that section into calmer thinking. But in his effort through administrative means to get those responsible for examination questions to think critically about the purpose and efficacy of their demands, I do see him as the outstanding contributor.

In other areas of chemical education Nyholm seemed to find it more effective if there were a number working at a problem, sometimes as a team, sometimes independently. The result is that he achieved a profitable atmosphere of progressive thought which had the strength of individual contribution and also the valuable bulk property of concerted action. The steps he and others took

[4] H. F. Halliwell, 'Chemical Education, Problems of Innovation', *R.I.C. Reviews*, 1968, **1**, 205

to achieve some of the goals stated in the Marchon Lecture[5] illustrate this. He was very committed to seeing that the science education which a pupil experienced really did help him to cope with the problems of modern life. So of course were many others similarly committed, but through his enthusiasm and vigour he had the knack of getting groups to be vocal and eventually to accept as normal, a discussion and a concern that previously would have been rejected as out-of-place: he was a major factor in getting the academic community interested in chemical education.

Details of the ways in which he helped the development of secondary and tertiary education are to be given and discussed by subsequent speakers. My point here is that Nyholm was one of the most vigorous influences in this last period of recurrent upsurgence to which I have been drawing your attention, and it is my belief that at this stage we reached the watershed in science education. Certainly two factors were aiding and abetting this recurrence to break through into a new era: the one was the increased volume of the clamour – and this came from those involved in teaching at secondary and tertiary level; the other was the change in the socio-educational framework – a factor from outside the teaching community. Nyholm had contributed in positive, encouraging but disciplining ways to the first factor: he was also aware of the onset of the second and was beginning to think of the quite new types of problems which would arise.

What justification do I see for thinking of developments in science education as entering at this stage into a new era? The line of demarcation, supposing my proposition to be justified, is unlikely to be sharp, but, accepting a gradual change, often with different areas of thought out of step, what differences should be detectable which would be qualitatively sufficiently marked to justify the statement?

I have spent some time viewing very briefly some of the changes which science education has been through in the past century and a half. *The point I now want to make is a two-fold one: partly it is that I see those earlier changes as ones which, over a century or more, took place within a well-established framework of educational beliefs that was widely accepted; and partly it is that in the future the acceptance will be much more parochial, and the older framework, already being antagonistically questioned in some quarters, may well be replaced for some by a contrary one.* We are close to the occasion, and only a provisional delineation is possible. It seems to me that the widely accepted framework to which I have just referred was one of transmission and communication from a knowledgeable and wise older group to an innocent and needy younger group who were clamorous for what the older had. The beliefs that were associated with that framework include, among others, belief in salvation through enlightenment by reason, belief in what is a Good Thing for the Chosen will be a good thing for the rest, belief that it is shameful for the older to acknowledge ignorance and shameful for the younger not to (in spite of ignorance and fallability being a common characteristic of the human race), and a belief that the acquisition of

[5] R. S. Nyholm, Marchon Lecture, 'Education in Science – for whom and for what purpose?', delivered at the University of Newcastle-upon-Tyne on 9th March 1964.

past knowledge automatically develops both judgement and informed adaptability.

I think it true to say that all the changes we have looked at so far have been urged by people who in spite of their mutual opposition would have subscribed to these values.

Some changes in the future are likely to be made outside them.

I am not saying that the older framework and beliefs will be utterly rejected. I am saying that they *are* being questioned. The impact of this questioning is difficult to foretell, but where the old values and framework continue, their continuation, because they are no longer the only possibility, will be based on a different criterion of acceptability, and the parochial nature of their acceptance (and it may be within a big parish) will mean that new techniques and intentions will develop as well as perspectives not previously imagined.

Nyholm was aware of the onset of the change of framework of beliefs and values, for he discussed with me the significance of the findings of a carefully and professionally conducted survey of opinions of undergraduates and staff of the purpose and worthwhileness of the undergraduate work in the chemistry department of one of the U.K. universities. There was evidence that the group was a capable one and, judging by details of its admittance, above average and able to stand comparison with many decades of undergraduates which the department had had. Nevertheless the academic staff felt that there were too many undergraduates who did not understand the value and importance of commitment to a problem of scholarship in a chosen area or of intellectual persistence and other traits and behaviours held dearly by the academic world. What was a shock, and I believe a valuable shock, was the evidence, not that these undergraduates did not understand, but that they had weighed these ideals in their contemporary balance and found them wanting: some of them, in fact, seemed to regard such attitudes as evidence of uneducated narrow-mindedness. Disturbing, if not painful, as we knew this must have been to those concerned, and limited in its coverage as it was, it fitted into what we knew of the contemporary pattern of student dissatisfaction and unease which was beginning to be worldwide. But the dissatisfaction of university students with academic fare has been common since this type of education arose many centuries ago. What was now appearing seemed somehow to be different. The impact of the variety of needs which arose from the explosive increase in the numbers involved in education all over the world – this impact, aided by the technological ease with which ideas spread round the world, brought about for many of the teaching world the need for reappraisal and a change of their own assumptions. It is unlikely, because of choice and selection, that this need for reappraisal will be as strongly felt in university science circles as in other university circles, or as it already is felt, and will be felt, in pre-university circles. Nyholm was certainly aware of the onset of this rejection of old values by some, and was aware that it would make new demands in his own university area – and also that it would make new demands in general on those involved in educational alteration and (hopefully) reform. It is these types of changes that make me speak of the water-

shed: the questioning of basic assumptions has, I believe, finally left an indelible mark.

It is the exploring, mapping, and inhabiting of what I see is for us older folk the other side of the watershed that is the major task for the oncoming generation. Trying to distinguish between profitable reconnaissance on the one hand, and foolish crystal-gazing and Polonius-like admonition on the other, I propose to look briefly at two of the broad areas of growth and change in science education which I have seen emerging since we were involved with Nyholm in the production of the Nuffield Project. I must, however, recall a comment which I made with the help of a quotation at the beginning of my lecture, and that is to stress that although new and unforeseen ideas will undoubtedly arise, there is still much of value in some of the older ones – providing, as we now see, that they are no longer regarded by their advocates as of universal application. For example, the separate sciences as we have known them will undoubtedly continue in some form to be of interest and value to a minority. However, their value for the majority will surely need to be re-assessed. Science education for the latter group may well take on a quite unpredicted form, and in exploring this unmapped area it would be well not to ignore a guide line offered by Huxley: 'What men need is as much knowledge as they can assimilate and organize into a train for action; give them more and it may become injurious'.

Let me then turn finally to these two areas where I think further exploration and development will be needed. If for this purpose I may refer to the four areas of decision making (Aims, Action, Assessment, and Adjustment) which I think must be the basis of any effort,[4] then the two on which I want to comment are in the areas, not of action or assessment to which our attentions rather naturally first turn, but in those of intentions and of reappraisal. Let me consider the latter first, because I think it raises problems which are fundamentally less complex.

The Machinery and Techniques for Reappraisal and Reform.—That some form of machinery which will enable adjustment to be made should be set up, we have long recommended. The form it will take I do not know, but the form it should *not* take I would have thought obvious: it must not be an imposition from outside. I shall want to draw your attention on two later occasions to the work of Edward de Bono on Lateral Thinking,[6] but at the moment I want to disagree with his statement (unless I have quite misunderstood his use of the word 'conflict') that 'we have never developed any tool for changing ideas except conflict'. I think that the serious offering of options and the setting up of advisory working parties are two such tools. I would have thought the Association for Science Education (A.S.E.) itself was a prime example. Indeed, in that particular body (in which Nyholm was so interested and involved, and of which he was President for two years) we surely have the foundation on which to set up this machinery for adjustment. If the Association were to develop, to working-party and advisory level, that side of science education concerned with further

[6] E. de Bono, 'The use of Lateral Thinking', Jonathan Cape, London, 1967.

education, technical college education, and university education (and that side is already represented in the Association), then the internal machinery for re-appraisal of the whole spectrum of science education could easily be available in an experienced and acceptable form.

When it comes to techniques of reappraisal, then I think that one of de Bono's comments[6] is of the greatest importance. He says 'being right at each stage is not enough in a sequential change', and I think this important because curriculum development *is* a sequential change. The importance that Nyholm and the Nuffield Chemistry team placed on the fourth area of decision making (Adjustment) meant that they were aware, though perhaps not so sharply as is de Bono, of the need to be ready to *rethink completely anew*, not just because feed-back shows one to be wrong in techniques, but because there may be evidence that from the beginning one had intentions which later (and only later) were seen to be inappropriate.

As an example of the need for reappraisal let me offer two items requiring re-exploration and re-development. The first is the question whether a system of assessment which has the community's confidence *must* be based on the importance of failure or whether it should or could be replaced by something based on achievement. At present, at each step of the ladder, 40% or so of the entry must be rejected: it is not a ladder – it is a sieve. Could it be that here is an undesirable hang-over from more than a century ago? Could it be that it is not the business of an Examination Body to 'pass' or 'fail' but to report on achievement and (hopefully) potential? We all know that a 'pass' in subject X at 'A'-level is a 'pass' but that a 'pass' in subject Y is often a 'fail' when it comes to University Entrance. In suggesting this problem for immediate attention I must point out that the production of a differently orientated examination system will not be difficult – it is the making it saleable and selling it that will cause bother.

A second problem needing attention is that caused by the great inhomogeneity of the groups now regarded normal as teaching units. Our university colleagues may think they have met this problem, but I assure them that they don't realize how easy life is for them, in this respect, compared with that in some school classes. The sample scheme of class-room action in the Nuffield proposals was based on the assumption that one would be teaching fairly homogeneous groups of fairly willing pupils: this was the normal pattern of classes till then. It will no doubt continue to be the pattern in some schools, but the pattern in many has drastically changed. Not only is there often a wide range of ability in many classes, there is at the same time a wide range of willingness – and the two ranges may show little correlation. The techniques of teaching and learning under these conditions are naturally only just beginning to be tackled: teachers – whatever their programme – need immediate help here.

I turn now to the second of these two areas where I think further exploration and development will be needed.

Resolving the Uncertainty of Purpose.—The natural questioning of direction which must accompany any new exploration was an initiating factor for this

uncertainty. So were the cries for greater pertinence from pupils and students (although pertinence for what was often not clear), but the uncertainty was undoubtedly enhanced by the neo-missionary activity to which I have referred. It is amazing how helpful to the diagnosing of one's own troubles can be the diagnosing of other peoples' – if undertaken with a proper sense of humility and awareness of ignorance. Those who have had experience of the growth of science education in the so-called developing countries have been lucky in having the opportunity to see the problem of purpose in their own country because they have seen educational activity in a sociological setting that is foreign to them.

I believe that the Nuffield Chemistry Project's reformulation of the A.S.E. Policy Statement, namely that our purpose was to help children to know when and how to be scientific about a problem, I believe that intention still to be a helpful and worthy one. The teaching of *how* to be scientific presents less of a problem than does the teaching of *when* to be scientific, which needs close co-operation between the teaching of science and the teaching of non-science. I can also see in our emphasis of the importance of a critical imagination and of the disciplined hunch, a near cry to Ramsay's for 'inventive powers'. Nevertheless we still need to evolve techniques for helping this imaginative thinking to develop in the laboratory and classroom – although I think that de Bono with his 'Lateral Thinking' is on the way to breaking through. But if (and neither Nyholm nor we would agree) it is taken that being scientific is the same thing as always questioning, then such an approach could be regarded as pernicious, and the cup of hemlock appropriately produced. But such a misinterpretation does occur; I would draw your attention to a report[7] of a comment by Douglas Whiting, Director of the V.S.O., speaking of products of our educational system that he has met in Asia and Africa. He says that many young people who come to him query everything – institutions, faiths, laws, and social structure. He goes on:

> "For this the schools must take credit because you have inculcated the critical approach, the ability to discuss and to express. Dr. Banda is constantly on edge about the tendency of volunteers to suggest to their pupils that they, too, should think for themselves, and he is not alone in this. Neither a one-party state nor Presidential rule thrives on 'Nuffield-type' education – which is a strong recommendation for it. But one sometimes feels that the question is eroding the powers of decision making".¶

Although the above is based on what I see as a misinterpretation of what Nyholm and the rest of us were trying to do, yet Mr. Whiting raises what I think is a very important point. What, in each subsection of man's communal living, is a wise balance between enquiry and decision-making (and how these opposing reactions are to be achieved) I believe to be a question which the next generation must answer. It is obviously linked with the question whether different

¶ The inverted commas round 'Nuffield-type' are my addition for reasons given above. H.F.H.

[7] D. Whiting, reported in *Review*, December 1971, Headmasters' Association, p. 168, 1969.

children should have different kinds of science education or whether all must have the same, regardless of its pertinence to their more balanced living.

If we go from decision-making on to exercising social responsibility we are entering an even newer field. There is a movement, and the Schools Council is concerned, which has devised a course of science designed to that end. And much opposition it is creating, for it makes quite new demands on teacher and pupil alike. The extent to which such a course will have to be redesigned, I cannot tell, but I am sure that for many if not for most, a course along some such lines will be the pattern in time to come. It is obvious that in the education of the non-specialist, *i.e.* in the education of the great majority of young people, there is a movement to expand the confines of science learning so as to join up with, and fuse with, the areas of non-science learning, with the areas of subjective and irrational value judgement, with the areas of 'ought' and 'ought not', and of purpose in life.

We hear much of integrated science (for the third or fourth time?) but this is a development in but part of the area. *If, however, we begin to develop science integrated with non-science then I believe we shall be walking into an area of light.* When I was at a conference on science education in Canberra, I heard a comment which impressed me considerably. The professor of physics at Brisbane, speaking of our pride of achievement in science, remarked that 'man prides himself on his logicality – in that [area], he is being surpassed by the computer. We should focus more on that which makes man unique – his illogicality'. Dr. Ronayne of Manchester in a recent article has gone further: he says,[8] 'While there is neglect of the social aspects of science in the education of the *scientist* the idea of responsibility will remain an unattainable goal'.

In a way the problem of variability of opinions of worthwhileness is but the other side of the problem we have just discussed. The former was regarded from the point of view of the seller, this from that of the buyer. Obviously these two points of view should match, but the latter group varies enormously in maturity, in ambition, in social and cultural background. Whether a young person considers his or her educational experience as worthwhile or not arises, I suspect, from sharply different sources according to whether the young person is one of the group going on, more or less voluntarily, to further education, or whether he or she is one of a still younger group trying to escape from a compulsory education system. Any problems in the former area are likely to be the more easily solved through a variety of optional courses: the problems in the latter area are going to be more difficult to overcome. I can point to them: I do not know their solution.

So for those going on from here there are new problems and new perspectives. I have indicated my reasons for thinking that the terrain on their side of the watershed will often be fundamentally different from what it was on our side. Should this turn out to be so, then many of the patterns of subjects, of examina-

[8] J. Ronayne, *Times Higher Education Supplement*, No. 125, p. 12, March 8 1974.

tions, and of administration on which *we* were brought up, will have to go. They will have served their day and those going on will have to devise and probe, to meet success and failure in areas we never thought of. A remark attributed to John F. Kennedy sums up the dual needs:

> Some men see things as they are and say why?
> I dream things that never were and say why not?

Ron Nyholm had both these capacities.