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ABSTRACT

Perspectives are provided on an historical and current analysis of the science curriculum movement. The overview specifically focuses on the curricular patterns of the 1960s which emphasized science instruction for the elite. Suggestions are proposed for defining characteristics that are essential in making a "science for all" approach effective. These suggestions include: (1) elite science education must be confined to some upper level of schooling; (2) science must be re-examined and recognized as a very varigated source of human knowledge and endeavor; and (3) clear criteria must be established for selecting the science that is to be the learning of worth with consideration given to the application of science and the excitement and power of scientific knowledge. Projects and programs in selected countries, such as New Zealand, the United States, Thailand, and Britain, are discussed as they reflect a "science for all" approach. (ML)

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SCIENCE FOR ALL

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There is renewed interest in science education in many countries after a depressed period of about a decade or more as far as co-ordinated or nationally supported curriculum efforts in that field are concerned.

New funds were announced in the USA in 1983 and a number of new projects have been established. In Britain a year earlier, the first major project since the 1960s was set up - the Secondary Science Curriculum Review. New Zealand was an early starter in this new phase with its Learning in Science Project in 1979, and its corresponding elementary school one in 1982.

Nor is this new activity confined to developed or industrialised countries. The Asia Region of UNESCO ranging from Iran to Japan endorsed in 1984 as one its few priority programmes for the rest of the 80s, one in the science education field.

In each of these, and indeed as the title of some, there has been a strong emphasis in the rhetoric and in the rationale on SCIENCE FOR ALL.

This slogan is a compelling and attractive one in societies where the impact of applied science and technology is manifest for all to see and experience via new products and new forms of communications. New jobs emerge and old and familiar ones disappear. There is a cry for new skills and expertise and a chronic toll of unemployed persons whose contemporary problem is often identified as a lack of these sorts of technical knowledge skills rather than as the fault of societies which used to need them as they are, but now cannot involve them in meaningful employment.

The slogan Science of All has a democratic ring about it as a curriculum target - something in it for everyone. Furthermore, as a target for a new era of curriculum effort the slogan also effectively acknowledges that science education in the past has not been SCIENCE for ALL and that large numbers of persons have indeed been failed or passed over by the science curriculum of the past and present.

It is, however, most important for those of us who are in the curriculum field and have responsibility to remember that this slogan or title, SCIENCE FOR ALL, should not be interpreted as being a new educational intention or goal. The early 1960s are too recent and too well documented to be forgotten so easily. There was much in the writing and hopes of that massive wave of science curriculum endeavour around the world which spoke, in the language of those years, of science education that was to enrich the minds of all students. Although this activity in the 60s was initially focussed on education in the more specialised disciplinary sciences of chemistry physics and biology, there were many projects in the 1960s and early 70s which aimed at the levels of mass education - elementary and junior secondary schooling.

By the late 1960s and early 1970s this wave of curriculum development had affected countries in all the regions of the world and the activity and exchange of ideas and materials for education in science was quite unprecedented in any other field of the curriculum of learning.

Historians of curriculum can take us further back to the late 1930s and to the turn of the century in Britain, to the 1880s in the USA, and even to the 1860s in Britain when indeed a very promising approach to a science education for all was quite deliberately and ruthlessly obliterated because of the threat it held for a number of sectors of the society of that day.

Accordingly, if we are to achieve anything in these present moves for SCIENCE FOR ALL we will do well to see what we can learn from these earlier failures and from the ways in which they, in fact, succeeded in providing an education in science, not for all, but a few.

The basic framework in which my discussion is set is that schools are established by society to fulfill a number of educational functions and that the curriculum in its parts and in its totality is both the instrument to serve these functions, but also it is the field where the competition between these varying societal demands is resolved.

If we focus on science we can identify some of the functions this subject can and does serve and these are diagrammatically portrayed in Figure 1.

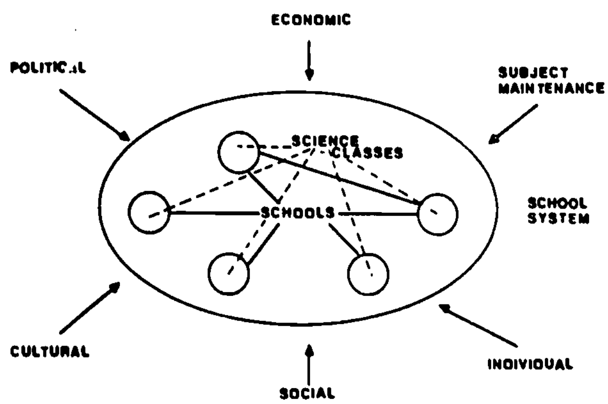

Figure 1. A diagrammatic representation of competing societal demands on schooling and on science education.

The sciences, particularly the physical sciences at the school level in many societies are gateway subjects that filter those relatively few who are allowed to move into the range of professions of status, social experience and economic security that now exist in all industrialised societies. Because of the social power associated with these positions we can call this function a political function of schooling.

Again, a limited but definite number of persons with scientific skills and expertise are needed in any society today to maintain and expand a variety of aspects of its economy - an economic few.

Scientists, particularly in research institutions and universities, are now a powerful sub-section who have a major interest in maintaining their subject as an elite and important field. Their interest will be very much to have the schools begin the process of reproduction of the sciences as they in higher education define them - subject maintenance.

In addition, there are clearly a number of ways in which all cultures and social life are now influenced by knowledge from the sciences and their application, and there is much potential in human inventions like the sciences for individual growth and satisfaction.

The first three of these social demands will be met, provided only a relatively small number of students are successful in learning the sciences at school. Indeed if a large number were successful these social needs would be threatened by over-supply - a situation with undesirable features that have manifested themselves in many countries since the 1970s when the demand for places in higher education from successful high school graduates has succeeded their availability and when persons with specialised training in science have been unable to find appropriate employment.

The other three functions, on the other hand, are ones that relate to the whole population and will only be met if large numbers of the student population successfully learn from that part of their total curriculum that is provided from the knowledge fields of the sciences.

Hence, I will argue that these two demands are not simply competing but, in fact, are conflicting. Unless this is recognised and allowed for in the curriculum design for science education and in its implementation, there is no doubt one will win at the expense of the other. Indeed, there seems little doubt which will win since one has the backing of national imperatives like the economy and spheres of political influence, and the other, in comparison, may be seen as a desirable but essential indulgence of the masses to do with quality of life rather than with specific urgent needs.

Let me now turn to some analysis of the science curriculum movement of the 1960s/1970s, and hence of much of our present science curricula, to discern some features of that phase that were, I am arguing, in the interests of the elite science education of the few, and not in the interests of the masses.

1. The first curricula to be redesigned in the USA, Britain, Australia, Thailand, Canada, etc. were those for the upper levels of secondary school where disciplinary sciences were taught, where only some of the school cohort study them, and where they clearly existed as a foretaste of further possible study in science.

2. The shape of the reform of these curricula was very much in the hands or patronage of well meaning academic and research oriented, disciplinary scientists like Pimentel at Berkeley for CHEM study and Nyholm at University College for Nuffield Chemistry, and similar distinguished figures in physics and biology. To consider the nature of the reform these project teams brought about, it is important to have a measure of what actually resulted in classrooms, rather than what the rhetoric of these 1960s curricula said was supposed to happen.

There is a lot in the descriptions of these courses and their guiding papers about the importance of the structure of the knowledge of these sciences and of the important role laboratory or empirical studies play in its development. The courses were also designed with the very clear intention that both these features of natural science should be very explicit in the teaching and learning of science.

In the event, in Britain and America the extent of direct uptake of these new courses and new materials was not nearly as widespread among local school systems as was hoped. Furthermore, in practice in these countries and in many others where evaluative reports are available, there has been a selective emphasis on parts of these courses to the detriment of the new curriculum's intentions as a whole. The role of the laboratory, as part of the nature of science or as means of learning the factual and conceptual knowledge of these sciences, has been a major area of neglect according to a number of studies. Most teachers and most examination systems seem also to have been unable to adopt the grand structural views of these science curricula. Rather they have turned them into conceptual statements, rules and formulae to be learnt without an adequate balance of the factual or of the realities of the natural phenomena to which they relate.

3. The teaching approach to this now heavily conceptual knowledge has too often followed a logical sequence determined by the significance of the knowledge in the discipline, and not by considerations of how it could be best learned. A concept is introduced, then defined,

then quantified, then refined, then applied to more differentiated examples of the original concepts, etc. This sequence of teaching is shown in Figure 2, each step of which is essential for the next but makes no sense of itself without a grasp of the steps that come earlier.

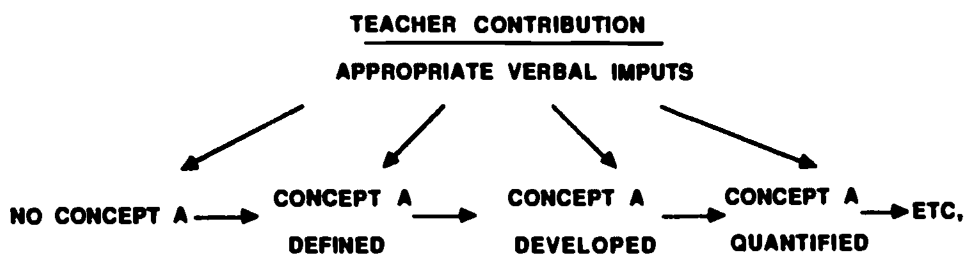

Figure 2. The teaching/learning sequence for conceptual knowledge in many science curricula.

Such a teaching sequence turns out to be well suited to the tasks of sieving and sorting the students in science classes into an elite few who become regarded as successful and a majority who are seen as failures and who reject science as being full of abstractions and little to do with phenomena in which they may indeed have an interest.

4. The science curricula for the lower secondary levels of schooling and for the primary or elementary levels were designed in a derivative way from this new thinking about the nature of science and its content for learning at the upper secondary level.

Thus we had a number of projects around the world where there was an emphasis on

(i) the learning of scientists' concepts at even very young ages. Projects like CONCEPTS IN SCIENCE, the Science Curriculum Improvement Study, were of this type. Another approach emphasised

(ii) the learning of what were called the PROCESSES of science - intellectual operations that are certainly used in the work of scientists but which in real life are never disembodied from the content of actual scientific phenomena or situations in the way they tended to be by these projects for students at school.

E.S.S. and AAAS Science-a Process Approach in the USA, and their derivatives around the world. Nuffield Primary Science and its derivatives, Science 5-13 Britain and many other international projects, sought to provide meaningful learning for all through a curriculum which was based on these intellectual processes that were then largely ignored by the teachers of secondary school science who did not see them as useful tools for their task of transmitting large amounts of factual, and conceptual knowledge. They were also quite misunderstood by parents and by the elementary school teachers who generally perceived science to be that body of scientific information they had failed to master during their own education at school or college.

The inadequacy of these earlier attempts to find a meaningful science for these universal levels of schooling is highlighted by comparing them with the situation in mathematics.

In the case of mathematics there is universal agreement that facility and understanding of the elementary number operations is an appropriate and highly desirable curriculum intention for the elementary school. Secondary school teachers want their students to have these facilities. They enhance the students' ability to learn not only the mathematics that secondary teachers want to teach, but also the learning of many other subjects in the high school years. Furthermore, secondary teachers are not trained for, nor do they want to teach, these elementary operations. Parents recognise these number operations as familiar and important for their children's living here and now, and for their future prospects. Society and employers add their endoresements to this sort of elementary school mathematics - perhaps more than they should in these days of ready accessibility to other forms of calculation.

None of these external recognition and support systems appeared for the science curricula which were introduced in the 60s and 70s for these levels of schooling where a Science for all might have been achieved.

In summary then, the science curricula of the 1960s have turned out to have the following characteristics.

(a) they involve the rote recall of a large number of facts, concepts and algorithms that are not obviously socially useful;

(b) they involve too little familiarity with many of the concepts to enable their scientific usefulness to be experienced;

(c) they involve concepts that have been defined at high levels of generality among scientists without their level of abstraction being adequately acknowledged in the school context, and hence their consequential limitations in real situations are not adequately indicated;

(d) they involve an essentially abstract system of scientific knowledge, using examples of objects and events to illustrate this system, rather than those aspects of the science of actual phenomena and applications that enables some use or control of them to occur;

(e) they involve life experiences and social applications only as exemplary or motivational rather than as the essence of the science learning;

(f) the role of practical activity in their pedagogy (if it is substantial at all) is associated with the belief that this activity enhances the conceptual learning rather than being a source for the learning of essential skills;

(g) their content gives a high priority, even in biology, to the quantitative aspects of the sciences.

These curricula have now often been successful in meeting the societal needs I have associated with elite science. In country after country where the reformed curricula have been implemented since the 1960s, the problem of an adequate supply of scientific and technical person-power has been solved. Indeed this is so in developing countries as well as in more industrialised and developing ones. Oversupply has occurred in a number of fields.

The main price of this achievement in science education has, however, not been just neutral for the great majority of students who are not, in the end, involved in this elite group. It has been that the majority of students have learned that they are unable to learn science - that science is not for them.

There are other prices also such as the degree to which the elite have to concentrate their later school years on the study of mathematics and the sciences to the exclusion of a broader curriculum. I would contend also that the elite, despite their concentrated learning of science, are also deprived of many aspects of learning science, that have been excluded from their school science courses.

This sort of analysis of the curriculum movement of the 60s and early 70s and hence of the present state of science in our schools can be used to begin to define characteristics that are worth suggesting as essential if science education is to be effective as a Science for All and others that are at least worth trying.

Firstly, elite or traditional science education must be confined to, and contained within some agreed upper level of schooling. It needs to be identified for what it is, namely, a form of vocational preparation. Containment is not achieved by offering alternatives at the levels of schooling where the Science for All is to be achieved. It is no good having a proper science for the few and a science for the rest.

These structual and organisational issues are crucial. The Thais have come up with one of the most interesting solutions to this problem. Their organisation of schooling and of science within it component curricula is shown in Figure 3.

		Vocational schools	Academic schools	
		(Broad vocational streams)	(Science stream)	(Humanities stream)
Upper secondary schooling	3 2 1	Specially designed science courses for each stream	Physics Chemistry Biology	Physical science
Lower secondary schooling	3 2 1	(All pupils) General Science		
Primary schooling	6 5 4 3 2 1	(All pupils) Life experiences (including science)		

Figure 3. The structure of schooling in Thailand and its organisation of science curricula.

Secondly, science must be re-examined and recognised as a very variegated source of human knowledge and endeavour. A much wider range of appropriate aspects of science need to be selected for converting into the pedagogicial forms of a science curriculum that will have a chance of contributing to effective learning for the great majority of students.

This is an epistemological task of a major order. It is, I suspect, a very radical task that is quite beyond the science professionals to whom we have always traditionally entrusted it.

To step aside from the intense socialisation into science that any of us who are science professionals have had, is almost impossible to do.

Our ensnarement into science and its ways of thinking about the world is too great.

For one thing, we have been specialised into only one or two of science's many forms.

Again, science educators are in addition socialised transmitters of a large body of scientific knowledge we have (in varying degrees) and they have not, in general, been either research or practising applied scientists or technologists.

Finally, our success, as all these sorts of science professionals in our own learning of science, has transformed us into persons who think about the world and natural phenomena in ways which are quite different from the child at school or the non-scientific adult in society who may or may not be very successful in our highly technological society.

To assist myself in this process of being able to think afresh about chemistry into which I was socialised, I have made a three dimensional model of the rich corpus of chemistry.

The facets of the model are all aspects of chemistry that chemists recognise as clearly within the confines of their subject chemistry. I can walk around it, stand back and look at it. I can even cut through it and look inside. I can see it is about products and raw materials, rich colours and material structures, it involves people at many levels and over time. It involves jobs and careers and materials that clothe and shelter and feed and heal. It involves ideas and concepts and numbers and symbols.

What have we made of this rich complexion of chemistry for schooling?

By and large we have reduced this fascinating corpus of chemistry to one of its least exciting two dimensional transects. School chemistry, apart from occasional visits to the laboratory, is the conceptual transect of this pulsating human adventure with colourful material substances. It is presented black and white on two dimensional pages of text books or on chalk boards or white boards. Its learning is checked by its learners' two dimensional responses to questions that are presented on two dimensional examination or test papers.

I have argued that present science curricula are really an induction <u>into</u> science. The ones that might provide a Science for All must be much more learning <u>about</u> and <u>from</u> science.

These curriculum processes are quite fundamentally different. Let me try to indicate this difference.

In the first we use teachers who have themselves been inducted into an acquaintance with some of the basic conceptual knowledge of a science to try to repeat the first steps of this process with their students. Since they (the teachers) usually have little experience of the exciting practical applications of their knowledge or of the process of trying to extend the knowledge of a science, the induction they offer into the corpus of science is via the same abstract route they followed as part of a former elite who could tolerate it and cope with its learning. Few of their students are interested enough to follow.

In the alternative that I envisage for a Science for All, the students would stay firmly rooted outside the corpus in their society with its myriad examples of technology and its possibilities for science education. Science teachers as persons with some familiarity and confidence with the corpus of science will need to be helped to be not inductors but couriers between the rich corpus and their students in society. As students move through school their experiences of society (school, home, community) will change, and they will encounter new situations to which science can contribute. Their teachers should dip in to the relevant parts of the corpus and from it, bring to their classrooms the science education that will empower their students to understand their world better and to believe increasingly that science and technology are great human inventions in which they can participate for their own and society's well-being.

Thirdly, some clear criteria must be established for selecting the science that is to be the learning of worth. These also will need to be defined from outside rather than inside. They will need then to be ruthlessly applied so that the pressure from the traditional views of conceptual, scientific knowledge can be resisted.

As an example of two such criteria that seem fruitful.

1. Aspects of science should be included that, in the society concerned, have a high probability of being used in a relatively short time by the students in their daily lives outside of school.

2. Aspects of natural phenomena should be included which exemplify easily and well to the students the excitement, novelty and power of scientific knowledge and explanation.

At a recent international curriculum workshop in Cyprus these two criteria were used to spell out a skeletal content for a quite new sort of science curricula. It was found that they did make sense in a range of broad topic areas such as Senses and Measurement, The Human Body, Health, Nutrition and Sanitation, Food, Ecology, Resources, Population, Pollution and Use of Energy.

In like manner we shall need to explore in the curriculum of Science for All what sorts of pedagogy are appropriate for the sorts of learning these much more variegated aspects of science require for learning. Again we must start from outside science for these pedagogies and consider much more the learners themselves and the constructions they already have about the natural phenomena we want to teach. Fortunately this is now a strong field of research in science education, and many of its findings are available. Again there will be an intense and interesting competition if the support teachers need for this type of pedagogy is to get its share of the new science projects' resources.

In conclusion I want to consider briefly what we already know of the shape of the new era of science curriculum development, and apply to some of its projects the criteria I have developed for SCIENCE FOR ALL.

Learning in Science

New Zealand science educators in recent years have contributed greatly to our understanding of how children learn science.

Unfortunately in using this as a base for reforming the science curriculum in that country they seem to have confused science content that was useful to elucidate these learning processes with content that is worth learning as Science for All.

Their emphasis on pre-conceptual knowledge as the learning of worth in the compulsory lower levels of schools will, I am afraid, take its place along side the conceptual processes of science that have been such failures from the 60s.

In the USA, the new reform got off to a somewhat disastrous start from the point of view of Science for All. The report on science education* that followed the Nation at Risk report contained some rhetoric of Science for All, but its substance was about the improvement of elite technical education.

It is incredible that a report on the need for and the role of science education could be written in 1984 and not refer once to the state of the world environment. It was as if acid rain, dioxane and continued nuclear testing did not exist. It had, internationally, a somewhat offensive but perhaps nationally necessary subtitle about making American students' achievements in science education the best in the world by 1995.

This, of course, implies that American science education is not the best in the world now, and that is a refreshingly humble note on which to start. However, to which countries does the report look for its comparisons and targets?

To Thailand which seems to have solved the structural problems of science curricula better than most and where girls do as well or better than boys in chemistry and physics?

To Tanzania and Kenya where the idea of personal technology is being used very effectively in school science curriculum?

* Educating Americans for the 21st Century. The National Science Board Commission on Precollege Education in Mathematics, Science and Technolocy, National Science Foundation, Washington, 1983.

To the Netherlands because they are in the forefront of relating physics learning to society?

To Nepal and Sri Lanka where elementary school science learning is being used as an effective instrument to enhance the lives of whole families?

No, the comparison that the Report contains has a strong sense of deja vu about it. It is 1957 revisited but the comparison is not now the Soviet Union but Japan, because of the technological and economic threats that country now poses for the U.S. So much for Science for All.

I have not examined in detail all the new curriculum projects that have been sponsored by the National Science Foundation. One entitled Project 2061 does have a strong emphasis in its rhetoric on Science for All. Alas its mechanism and procedures seem very much to be yet one more go at the processes that failed in the 1960s. Teams of Scientists (excluding science teachers!) are being brought together to try to answer from their blinkered perspectives "What science do students need to learn?" No non-scientists are included, there is no voice from the many successful people in the USA who, in scientific terms, are scientifically illiterate. There is no voice of the dispossessed. It appears again to be a well intentioned look outwards, from well within the corpus of science.

The Secondary Curriculum Review in Britain has used as its basic source of ideas and pedagogy the exemplary work of innovative science teachers in schools who have been successful with broader groups of students. This approach seems to have much more prospect of tapping into those outside-of-science views that on my thesis are essential for Science for All. The greater problem for that country, with its propensity for social stratification, is likely to be how to provide recognition that this sort of science is important for all and is not just an alternative for those who cannot cope with the "real" sciences of traditional school chemistry, physics and biology.

CONCLUSION

Science of All is a vision splendid. Like any worthwhile vision it recurs to lift the spirits of those who have become depressed with what they and others are achieving with current ways of doing things. In the 1930s, Lancelot Hogben, with his book Science for the Million, offered a vision to educators who began what has been called 'the general science movement'. In the late 1950s the vision came again and science educators tried again - as part of the science curriculum movement of the 60s/70s. In the 1980s the vision is clearly before us once more. The shape of the responses to it in the next decade are now being formed. Their adequacy will depend very considerably on how clearly we can read the realities of the earlier attempts and realities of the very different social and educational situations of the current day.

A fundamental difference between the sort of science education (and hence curricula) that we have had hitherto, and what may be needed for a genuine science for all is the fact that the all must be thought of as being outside of science.

In other words, science is an institutionalised part of all our societies in very definite and varied ways. On the other hand, even in the most highly technical scientifically advanced societies there are certainly not more than 20% of the population that one could even generously identify with that institutionalised part. The 80% of the population are, and for their lives will be, outside of science in this sense. Furthermore, the 20% who may, or do, belong within the institutionalised aspects of science, also spend much of their lives in those spheres of society I am seeing as outside of science.

It is this sense of outside of science that I think we must understand and translate into curriculum terms if SCIENCE FOR ALL is to succeed at all from our present opportunities.