THE PURSUIT OF SCIENCE AND TECHNOLOGY MANPOWER IN THE 1980s: Some Conceptual Problems

Kenneth King

AN INTERNATIONAL REVIEW MEETING ON
EDUCATION, SCIENCE POLICY, RESEARCH & ACTION
INTERNATIONAL DEVELOPMENT RESEARCH CENTRE
NEW DELHI - JANUARY 10 - 13, 1984

The pursuit of science and technology manpower in the 1980's Conceptual problems

> The proposed council (of higher education) and the Ministry of Education, Science, and Technology will help the country more if they borrow a leaf from such newly industrialised countries as South Korea and Singapore, among others. These countries emphasised on scientific studies right from the beginning of the learning process. Through exposure to science, students learn that the discipline is not as mysterious as they might have been led to believe. This leads to more students opting to follow scientific or technical careers rather than artistic ones. In a world in which technological advances are made almost daily, this gives those countries an advantage over others that pay less attention to scientific studies.
>
> The Ministry of Education, Science and Technology should accept the fact that like building a house, you can't begin teaching science from the top. It has to begin from below at the pre-primary level.[1]

This editorial, coming on the eve of the 20th anniversary of Kenya's political independence, mentions many of the issues with which we are concerned in this conference, and not least the notion that certain Asian nations have pioneered strategies for the systematic investment in science and technology which have had major consequences for their industrial development. As Kenya is not alone amongst the less industrialised countries in wishing to follow some such science-based development path, it will be useful for this meeting to examine whether any such strategies or models exist, whether they have any implications outside the particular political and economic settings where they were tried, and what some of the individual ingredients of such policies might be. That task is much beyond the scope of this present paper. However, as a step towards organising thinking on this and related questions, it is perhaps useful to sort through some of the sets of material that are beginning to accumulate in this area, and to outline some of the interactions that may be necessary in these literatures if they are to play any part in an integrated analysis of science-based development.

Rather early in any such exploration, it becomes clear that in many quarters an advocacy literature in favour of science and technology is rapidly developing. Like the high level manpower

[1] (Editorial 'Science: Preparing to Join the Club' in Daily Nation, Nairobi, 9th December, 1983, p. 6)

literature of the early 1960s, many of the assumptions about 'investing in science and technology' are not examined, and, in particular, little attention is paid to the processes whereby scientifically-educated students are utilised in the economy. Expectations run high about the way that science training can be converted into technological development, but in much writing there is little clarity about processes and mechanisms whereby this might happen. As with the earlier arguments about levels of literacy and 'development' or the impact of high level manpower, rhetoric and intuition carry the day. With this difference. The positions being taken by politicians and Ministries of Education, Science and Technology are at face value even more persuasive than their predecessors. It seems almost as if the whole critique of modernisation theory and of manpower planning over the last 15 years has been forgotten as nations set their sights to join the Science Club. The logic is however particularly compelling to countries that have successfully localised their public services since the end of colonialism but still find themselves technologically and industrially dependent on external economies. The prima facie argument is strengthened moreover by the presence in the 1980s (unlike the 1960s) of a set of countries that appear in some sense to have 'made it' by what is interpreted as the single-minded application of science and technology to their entire society.

Nor is this highly instrumental approach to the manipulation of science and technology reserved for African admirers of the various S. East Asian and South Asian experiences; it is also to be found very conspicuously in the current political debate about the role of the universities and industry in Britain. One strand of the government's strategy for higher education in the 1980s is precisely to have an impact on industry's competitiveness by the application of 'new blood' to scientific and technological training.

Even if the political debate about scientific investment seems little more sophisticated than the earlier more general rhetoric about high level manpower investment, there do now exist sub-literatures on different parts of this complex process of human resource application. In combination these should be beginning to make us cautious about loose usage of much of the terminology involved in scientific transformation. In particular they are requiring much greater clarity in the use of terms like indigenous technological capacity, scientific and technical manpower, degrees of skill and semiskill, scientific creativity, adaptation and dependency, technological training, transfer, and choice. The thrust of these various analyses would suggest the following directions:

> From a preoccupation with numbers of scientists and technologists to a concern about patterns of their utilisation;

From discrete education planning and science-and-technology planning to a view of their necessary integration;

From a one-world view of science and technology to an understanding of different science and technology environments.

In approaching these and other research and policy questions, there has, until recently, been a tendency for educational and S & T Planning to be concerned with two quite different universes. The former had been almost exclusively concerned with in-school matters, - student numbers, school location, curriculum reform, teacher requirements and many other issues. Science and technology planning by contrast was concentrated on the need to formulate a technology policy, develop policy instruments, and consider advice to government on large scale, intermediate and small scale technology sectors. Twenty years ago the then new discipline of educational planning was rather more concerned with the world outside school, and via the manpower-planning enthusiasm of that era participated in the hope that the production of high level manpower could directly influence the economic development of a nation. With the retreat from the more naive versions of investment in education for development, educational planning retreated also into school-based matters until the arrival of this new optimism about investing in science and technology. Unlike the rallying cries of the first development decade, 'Higher Education for Development', 'Education for Modernity', 'Education, Manpower and Economic Growth', the current calls for investment in scientific and technological capacity sound much more directed. Not just higher education, but very specific forms of exposure to scientific and technological training. It may be useful accordingly to examine some of the assumptions that lie behind the policy declarations on science for development, coming from a selected number of documents and agencies.

a) The role of science and technology education in national development.

Typical of this new and more specific form of the old coupling of education and national development is the report from the Unesco-sponsored International Congress on Science and Technology Education and National Development (December 1981). This congress in turn derived from the interest surrounding the U.N. Conference on Science and Technology for Development, and can be seen as an attempt to make more explicit the human resource implications of that wider U.N. agenda.

What is interesting about the Congress report is the strength of feeling about the potential of science and technology. A direct correlation is asserted between a high rate of scientific and technological growth and economic growth. Interestingly enough it is admitted that 'the significance of education in the development process is not so clear' (para 10). Nevertheless, there is much more certainty about science and technology education. 'The conception of science and technology education for national development...conveys a lot of optimism and hope'. It turns out that science and technology education can directly contribute to a country's primary health and nutritional care, as well as to the UN rights to be free from want and to exploit natural resources in appropriate ways. Beyond this, science and technology education can apparently help to ensure more effective control of population growth rates, and can play 'a vital role in solving the most urgent problems confronting the world'. Science and technology education have the ability to help utilise to the full society's human resources in agricultural and industrial activity.

According to the Unesco document, the progressive incorporation of science and technology into every part of the life of societies, through formal and nonformal education is one of obvious ways of producing the above and many other developments. Science and technology education seems to have a comparative advantage in producing that degree of rational thought required for the transformation of society; the list of attitudinal and cognitive changes expected is rather extensive:

> Such informoration should also make it possible to provide young people with the kind of values and attitudes and the powers of rational thought, expression and behaviour that fostered the development of both the individual personality and of an intellect that could adapt itself to a rapidly changing environment and find the right answers to the unpredictable challenges the future may bring.[1]

The picture that emerges from the Report is of the indispensability of science at all levels of school and society, informing policy makers, teaching the art of intelligent decision making, helping the ordinary citizen to organise his or her own concepts and attitudes. To cap it all, science and technology education, it is claimed, should also be 'considered as an important element of preparing society for individual happiness and collective peace'.[2]

There seem to be very few hesitations about the positive impact that comprehensive science and technology education can have on developing societies. Science education for all, both in formal schools and in science popularisation campaigns, is portrayed in such favourable terms that it would be difficult to vote against its adoption. There are, however, just a few notes of caution that are entered in the course of the document. One relates to the question of promoting endogenous science and technology, and the second to the possibility that science and technology education may not automatically lead to the rational use of resources.

The issue of endogenous development of science and technology implies that science and technology has somehow to reconcile the

[1] (Unesco: International Congress on Science and Technology Education and National Development. Final Report (Paris December 1981) p. 6).

[2] (IBID p. 9).

importation and application of new technologies with the selection and modification of existing, traditional technologies. But there seems to be something of a contradiction at the heart of this strategy. On the one hand a main reason for the backwardness of developing countries in agriculture and industry is allegedly 'the lack of scientific attitudes in the public at large'[1]. At the same time it is recognised that all countries have over the years developed 'a store of knowledge, skills and experiences which have enabled them to survive by harnessing certain aspects of their environment'.

Rather than abandoning all such traditional lore in favour of imported modern technologies, 'efforts should be made to identify any scientific roots in these traditional practices and to base future development on them'.[2] What is really being admitted is that there are both 'scientific' and 'non-scientific' beliefs in traditional peasant communities (or by extension in developing countries). The latter are clearly a major obstacle to the advance of western science-based modernisation strategies. The former may in some sense be allies.

This perspective immensely complicates any genuine attempt at science popularisation, and the role of the formal school in any such campaigns. Acknowledging that indigenous technical knowledge is both 'scientific' and 'non-scientific' means that the school has the rather delicate task of sorting out appropriate from inappropriate technologies, and 'good' traditional lore from 'bad'. Furthermore, although schools are encouraged to conserve and transfer these elements of 'good' traditional lore, it is clear that even with these Unesco believes there will be a need to encourage a new more creative, questioning approach. This suggests that behind the apparent encouragement of some elements of traditional knowledge systems lies an assumption that even the good will need to be subjected to an invigorating dose of western criticism and creativity. In other words, some of the endogenous beliefs may correspond to western scientific beliefs but the attitude towards them of the people who hold them continues to be insufficiently scientific. The lipservice towards indigenous knowledge systems is neatly captured in this paragraph:

> The school should serve as a vehicle for the transfer of such traditional technologies with emphasis on the continuity of the society and its accumulated knowledge, skills and experiences. The teaching of this traditional and cultural heritage, however, must <u>encourage a sense of scientific/technological creativity</u> in relation to the local environment. Efforts need to be exerted to convince teachers of the great importance of encouraging <u>creativity</u> among pupils at all levels.[3]

[1] (Unesco: International Congress on Science and Technology Education and National Development. <u>Final Report</u> (Paris December 1981) op.cit. p. 4)

[2] (IBID p. 4-5).

[3] (emphasis added. IBID p. 5).

The attempt to maintain a balance in the Unesco prescriptions between a very eclectic approach to traditional culture and belief systems on the one hand and a strong encouragement to spread western science and technology is not very successful. The axiom 'science for all' is implicit in much of the argumentation, but it is clear from the context that it is major injections of western science and technology that are referred to in this message. Indeed, there is talk of the need for the living local traditions even in the poorer communities to be opened to this 'effective scientific knowledge and techniques for solving their present problems', with the hope that there might be through this a qualitative leap forward to narrow the gap between the industrialised and poorer countries. The document proceeds to underline the part that could be played by computer science and information technology 'to improve national capacities for the management of development, and by biotechnology to meet the basic needs of the population in nutrition and health'.[1]

If there is very little analysis in the document of the complex interactions between local knowledge systems and western science, there is even less appreciation of these aspects of the impact of western science and technology that have been so widely criticised both in the West and in developing countries. Only in two short paragraphs in the whole report is it admitted that science and technology education might have effects other than those outlined at some length above, and even then there is very little exemplification of the possibly non-constructive role of science and technology:

> Science and technology are not a panacea for solving all the problems confronting humanity today. If not developed and used with discretion and control, science and technology can prove counter-productive and may even run contrary to the above mentioned larger goals of realising human rights and satisfying basic human needs. Some negative effects have been felt during the last few decades.[2]

There is little or no commentary on this bald last sentence or two beyond some reference to ways in which science scores are abused to stream children in school or turn girls against science from an early stage. There is certainly no comment on the supposed neutrality of science and technology, nor on the rather large literature on social responsibility in the sciences.[3] In a word, the paradigm presented by this influential Unesco document is of a basically benign campaign to broadcast widely through the Third World modernisation via the sciences. There is some lip service to local knowledge, but it is apparent that this lacks the critical, creative characteristics associated with the western scientific enterprise. Although the Unesco document is

[1] (Unesco: International Congress on Science and Technology Education and National Development. Final Report (Paris December 1981) p. 6)

[2] (IBID p. 5)

[3] (See for instance the literature associated with the Science in a Social Context Project - SISCON)

principally concerned with promoting science and technology for all, via formal and nonformal education channels, it has little to say about the way all this scientifically trained and educated manpower will be used. The preoccupation is more with the adjustment of science curricula in school and university than with the utilisation of educated scientists and technologists. Paradoxically, the Unesco Congress was intended very deliberately to put an education dimension on to the earlier UN Conference on Science and Technology for Development, but there is little help for educational planners or science and technology planners concerned with translating educated scientists into policies for development of science and technology in the economy at large.

b) Planning Education and Training in Dependent Political Economies.

We have noted that the UNESCO report argues for more science and technology education within what may be loosely termed a modernisation-via-science perspective. There is virtually no reference at all to the process whereby 'Northern' science and technology is transferred to Third World countries, nor any comment on the terms and conditions on which the Third World learns from the North. There is no suggestion of possible conflict between the interests and priorities of industrialised and industrialising countries. Other questions which are not addressed are: the impact of high technology education in countries with a fragile industrial base; the extent to which it is possible to overinvest in science and technology education; the possibility of educated unemployment or under-utilisation of highly educated or trained scientists; the match between the science and technology curricula of the North and the South. However, these and many more are precisely the issues that must be discussed in any integrated attempt to plan science, technology and education.[1]

So far these has been little attempt in the planning literature on science, technology or education to examine their interactions in a North-South context. One move, however, towards such a perspective is contained in a discussion document by the International Institute for Educational Planning (IIEP) in Paris. In this the theme of 'Educational Planning and Technological Development' is selected as one of the main thrusts of the Institute's research attention over their next plan period.

It is immediately clear that the treatment of the North-South relationship and the Education-Technology relationship is very different from the UNESCO document.

[1] (For an elaboration see K. King, 'Science, technology and education in the development of indigenous technological capability' in K. King and M. Fransman, Technological Capability in Developing Countries (Macmillan, London, 1984)).

First it is assumed that education planning cannot satisfactorily be undertaken without analysing technical change, whether external or internal, and its impact on training needs and qualifications. The tendency to plan education as if it was an autonomous sector and to ignore this perspective on technological change and technical capacity is one reason, the Report alleges, that African countries remain so dependent on expatriate technical expertise. Clearly also, blanket perscriptions of science and technology education for all are the very opposite of this IIEP approach, for without a sense of the direction of technical change, a developing country will be expanding its science and technology capacity in the dark:

> Increasing the number of skilled workers, specialists and technical managers without regard to the changing demands of (often imported) technology leads to still further shortages of certain types of qualifications and to a surplus of others, higher education included.[1]

Second, since technical change is principally located at the moment in Northern industrialised economies, educational planning in the South must as far as possible be aware of the nature and implications of this technological dependency. The dependence of the South on the North, and of the education sector on the wider economy is set out very starkly as follows:

> If educational objectives cannot be defined independently of technological change, and if the latter is mainly of external origin, educational planning in the Third World must plainly give proper regard to the worldwide conditions of production and movement of techniques. These conditions set limits to its effectiveness.[2]

In stark contrast to the Unesco document which presented science and technology education for all as a readily available commodity which most developing countries could acquire and distribute very widely the IIEP analysis is extremely concerned with the source and conditionality of science and technology education and training. So far from being a good whose supply can be turned on and off like water, the source of science and technology education and training is already highly influenced (if not contaminated) by patterns of technical change and its associated education and training in the industrialised countries. It is argued that the intimate connection between scientific and technological development in these countries and the increasing specialisation in civil and military design and production have led to a situation where the majority of countries are now excluded from the production of new technical and scientific knowledge. "The most advanced among them (Third World countries) at best produce equipment for the consumer and intermediate goods industry, and

[1] (IIEP, Introductory Document at workshop on 'The prospects of educational planning related to contemporary development problems' 3-8 October, 1983, Paris p. 8)

[2] (IBID p. 9)

in any case their R and D capabilities are far too inadequate and rarely directed to their own needs". 1

With the increasing speed of technical change in the North, and the concurrent internationalisation of its products in developing countries, the world of scientific and technical development has become rapidly polarised. The qualifications required in the Northern science and technology environments will continue to emphasise integrated design and development capacities, whereas the constant importation of increasingly specialised machinery and knowledge in the South will emphasise compartmentalised capacities, restricted to the utilisation of products rather than aimed at their production. The kernel of the IIEP analysis is the contrast between these independent creative and producer capacities in the North and the dependent user skills in the South:

> Generally speaking, the qualifications and skills required to use external technology cannot lead to the capacity to reproduce and adapt this technology, and a fortiori, to the capacity to innovate in response to the host country's needs and resources.[2]

Although the contrast between user and producer knowledge, and as a corollary between passive and active scientific research environments may appear overdrawn, it does fit in with some thinking in India on the creativity of the science community. It has been argued that the free availability of foreign technology through collaborations has a very direct impact on the nature and utilisation of Indian scientific and technological qualifications. Creativity in the scientific community cannot be combined with an ideology of wholesale foreign collaboration. So, states Dinesh Mohan, 'the industry's foreign collaborations end up influencing what happens in our academic institutions'.[3]

The solution to this technological and cultural dependence of so many Third World countries must come from a deliberate attempt to develop local technical creativity, argues the IIEP proposal. In this task, again, education planning is inseparable from industrial and technological planning, but, providing the state can decide on a coherent policy of indigenous technological development, - e.g. the manufacture of strategic, multi-purpose capital goods, then education can begin to have a much more autonomous role: 'Education should contribute to the development of the ability to select and apply techniques, to design machinery and to produce technical and scientific knowledge'.

[1] (IIEP, Introductory Document at workshop on 'The prospects of educational planning related to contemporary development problems' 3-8 October, 1983, Paris p. 11)

[2] (IBID 15-16)

[3] (Dinesh Mohan, 'Retooling' Seminar, January 1983, p. 4)

This approach to indigenous technological development must inevitably be selective since there can be no question of reproducing the production system or the research and development system of the industrialised countries. Acknowledging this is perhaps the most politically difficult part of the strategy. Compared with widespread access to dependent foreign collaboration, it may seem politically unacceptable to argue for self-reliant design and development in only a small sector of the economy. Interestingly, this issue of selection is precisely that which Dinesh Mohan has fixed on as an essential starting point for 'retooling' India's dependent industrial economy:

> We must decide which goods are essential for a vast majority of our people and concentrate on manufacturing them without foreign help. We can choose a few critical items where we may still need some foreign collaboration for the short run. But even in these the onus should be on the manufacturer to demonstrate the technology is beyond our present capabilities.... We must (also) aim to produce a few manufactured goods with a high science and research content which must be considered the best in the world. [1]

In both Mohan and the IIEP document there is something of a tension between a basic needs approach to the capital goods sector, with self reliant design and production of items feeding into mass markets, and the desire to encourage some basic research in new technologies which could rapidly lead to the establishment of some comparative advantage by such Third World countries. 'Fields such as energy, biotechnology and computer sciences could provide opportunities for Third World scientific and technical research to achieve decisive results fairly rapidly'.[2] These latter fields are particularly attractive since they offer apparently an opportunity to move rather rapidly from educational investment to industrial application without massive infrastructural developments.

The rôle of educational planning of science and technology manpower is clearly going to be very different in the IIEP and the UNESCO paradigms. In the latter, science-for-all perspective, the emphasis is on quantity, bringing the good news of science (from the West) to all men, lightening the darkness of peasant myth and suspicion, and converting men to see that science, like the holy spirit, is omnipresent and all powerful. In the words of one of the more recent characterisations of popular science in India:

[1] (Dinesh Mohan, 'Retooling' Seminar, January 1983 op.cit. p. 5)

[2] (IIEP, Introductory Document at workshop on 'The prospects of educational planning related to contemporary development problems' 3-8 October, 1983, Paris p. 20)

> Science is all around you and everywhere. The methods of science allow you to understand, make observations on, question and alter your immediate environment (that is technology) to your advantage.[1]

The manpower implications are almost by definition somewhat vague, when so many categories of person in rural and urban areas are required to adopt a scientific approach. Nor is there any particular concern about the North-South flow of science and technology, or the extent to which local creativity can emerge from dependent science and technology environment. The IIEP frameqork, by contrast, possibly overdraws the technical and cultural dependence of the Third World, but is properly clear that the promotion of science and technology capacity in the South is inseparable from a critical analysis of the direction of science and technology in the industrial heartlands of the OECD countries.

c) Structural Problems in Technological Self-reliance

It may be useful to carry further the exploration of the key ingredients of technological self-reliance by examining the situation in a very different political economy, where scientific and technical capacities are in very short supply, and where there is no thought of satellites, nuclear technology, or the production of silicon chips. Yet in Tanzania, it is possible to examine some of these same essential themes: technological dependency, the science and technology environment, creativity, comparative advantage, and the role of peasant knowledge in relation to science. A joint UNIDO-Tanzania Government document[2] is frankly sympathetic towards Tanzania's declared goals of socialist transformation, but outlines many of the structural obstacles in its way. It thus provides a useful overview of these related issues.

One of the first necessary clarifications made by this document is the difference in kind between the science and technology systems of the North and the South, and the consequent lack of a similar rationale for teaching science and technology in the developing countries:

> Let us here point to the fundamental differences in the science and technology systems in industrialised and developing countries. Those in the industrialised world are characterised by the fact that the evolution of scientific activity has led directly to, or is clearly linked with, advances in production techniques, whereas those in the developing world generally are not. Industralised countries can thus be described as possessing an endogenous scientific and technological base, and developing countries as having an exogenous technological base.[3]

[1] (Narender Sehgal, 'Science and Technology: Why and What to Popularise'?, mimeo, 1983 p. 4)

[2] (Development Strategy and Technological Transformation in Tanzania: the Limits to Self-reliance, August 1981)

[3] (IBID p. 85)

The relation between the science and technology experience in education and that in industry soon becomes rather close. If there are few if any positions for design and development work in industry or agriculture this is soon reflected in the hidden curriculum of education, whatever the similarity of syllabus between Europe and Africa. Even if the school and university promote science-for-creativity, following American or UK models, the lack of an organic linkage between knowledge generation and production will lead to the science course becoming a credential rather than a foretaste of basic research or technical application. The bureaucratisation of science and engineering graduates soon has a backwash effect on the education system itself. [1]

The UNIDO report also follows the IIEP in seeing the skills and training needs as intimately bound up with the imported technology. Too often educators and trainers think of skills almost as disembodied, to be promoted (like science) for the rapid transformation of society. Instead, it is clear that a significant part of Third World skill training is related to the maintenance of imported technology. It is particularly true of skills that are institutionalised in national centres and polytechnics, but it is also true of project related training, where, as part of the total foreign project, those skills essential to the maintenance of the plant are delivered as part of the agreement. There is not unnaturally a tendency for such skills to be highly fragmented, site-specific. It must of course be remarked that the fragmentation of skill has been dramatic in the industrialised world, and in this respect there is an important difference between science and skilled work within the OECD countries. Both have become more specialised, but science has gained status with specialisation while skilled labour has lost status by the same process of specialisation and fragmentation. Because of the slower pace of industrialisation in developing countries, accordingly, there has been less deskilling of traditional skill categories. And even in the capital and intermediate goods sectors in developing countries, it is likely that the much slower pace of automation has left intact many of the shaping, fitting and turning skills that have been eroded in the West by new generations of numerically controlled machine tools.

Apart from commenting on the North-South differences in the science and technology environments, the UNIDO report provides some valuable counterpoint to the UNESCO and IIEP reports in the matters of technological creativity and endogenous technology. We noted that in so far as the UNESCO report dealt with innovation or creativity, it saw them as the accompaniment of the

[1](Mohan comments on the same phenomenon in India where he alleges 'there are very few challenging technical or scientific jobs offered by Indian industry, op. cit. p. 4)

spread of scientific temper for all. The IIEP document doubted their emergence in any highly import-dependent regime, where technical change was always linked to new foreign collaborations or direct foreign investment. It argued that creativity almost needed to be protected by policies of selective indigenous development of technology. The UNIDO report on Tanzania goes a stage further and situates the issue of technological innovation within the larger capacity of the society to innovate. Thus, scientific or technological creativity is unlikely to emerge from merely putting into place appropriate technology institutions, capital, and know-how. Even linking organically the capacity for science and technology with productive and educational systems may not be enough; or introducing the appropriate fiscal and trade policy regimes. The social and cultural milieu outside the boundaries of the science and technology elite will be critical. This emphasis on mobilising society takes us back by a different route to the 'science for all' approach, with this distinction, that there is a strong assumption about peasant creativity on which wider policies of innovation can be built. Dissemination strategies will obviously differ depending on whether it is assumed that peasants need science brought to them from outside as opposed to a conviction that some significant resources of knowledge and technology already exist:

> (A society's capacity to innovate) requires mobilisation of the creative energies and problem-solving capacities of a nation's population. It requires conscious policies designed to trace the survival knowledge and technologies 'hidden' in local communities, among the peasantry and in the experience of women. <u>The development of a real capacity for innovation thus requires not only the mobilisation of the technology system but also the social system</u>. Attitudes and motivation throughout society will determine the climate for innovation.[1]

In this connection it is useful in passing to note that in Korea, Hyung-Sup Choi has argued that it was not alleged unscientific peasant mentalities but infrastructural and communication problems that had to be addressed in creating a national science and technology climate:

> Contrary to the widely held view that a change in rural values and attitudes is a necessary precondition if there is to be a self-sustained change in rural economic behaviour, there have been studies which support a different view. Government efforts have placed, according to its assertion, less emphasis on farmers' psychological motivations and more on furnishing essential assistance to agriculture in terms of

[1](UNIDO op. cit. p. 94 emphasis added)

credit and technical advice and by providing linkages between the villages and the national economy.[1]

If it is accepted that technological innovativeness in a nation's urban factories and research labs is ultimately unlikely to be dissociable from a wider climate of change and infrastructural development in the rural areas, then this does raise some serious research and policy questions for countries pursuing strategies of 'indigenous technological capability' without corresponding change in the rural-urban imbalances of income, opportunity and infrastructure. Is it for example the case, as the UNIDO report would argue, that 'it would seem reasonable to conclude that it will prove impossible for all developing countries to effectively embark on their technological transformation without a corresponding social and political transformation?'[2]

Or are there examples where technological innovation has taken place on a very small base of scientific and technical literacy? These and other questions about the limits of technological innovation and self-reliance are very germane to the many small action groups and science centres concentrating on rural development without any expectation of their efforts being reinforced by any wider incentives to change. Indeed, one of the problems about separating technical from social and political change in the countryside is that in some countries the most conspicuous examples of new technologies or dramatic technical change have been those associated with direct threats to the continuance of peasant communities and their autonomy. In many cases, it sounds as if discussion about the value of science campaigns for rural areas assumes that peasants have had little contact with the transforming power of applied science. Quite the opposite is often the case; peasant producers have frequently witnessed the application of new technologies within existing rural power relations, in new high yield crops, new systems of forest or mineral extraction and other areas. Over against some of these alliances between new technologies and political elites in rural areas, the rhetoric of science for all or the search for technologies hidden in rural communities start at a great disadvantage.

d) <u>Issues in the analysis and utilisation of scientific and technological manpower</u>.

There has until recently been something of lack of interest in manpower planning, following the spate of national manpower plans of the 1960s and the subsequent disillusionment with their value as a tool for economic and educational planning. In the last year or two, however, some new questions and approaches have begun to be mentioned in connection with manpower, and particularly in relation to scientific and

[1] (Hyung-Sup Choi, 'Creation of science and technology climate' mimeo, no date, p. 17)

[2] (UNIDO op.cit. p. 99-100)

technological manpower. One reason for the relative lack of recent manpower plans has been the absence of newly independent countries in the last fifteen years, and another has been the disenchantment amongst many international agencies with the whole emphasis on high level manpower. With the independence of Zimbabwe, nevertheless, the occasion was taken to organise a national manpower survey, and it is interesting to note the extent to which that survey has sought to look with fresh eyes at many of the most basic manpower and labour market issues. Several of these are of direct relevance to countries at very different stages of industrialisation and development.

The first and most basic assumption of the Zimbabwe National Manpower Survey is that such a survey cannot avoid being both a technical and a political exercise. This is worth stressing, particularly on the science and technology side, since many of worker categories (scientist, engineer, skilled man, technician, etc.) sound as if they have an international currency and would not change significantly from country to country. The fact is that most of these categories are in some sense socially and politically constructed, and in the case of pre-independence Rhodesia, affected by white settler ideology and racial politics. The Report is able to show convincingly that the category 'semi-skilled', for example, is racially determined to include large numbers of blacks who were technically-speaking skilled, but who had to be distinguished from direct competition with white artisans. At the other end of the scale, the Report argues that the almost inevitable reaction at independence to these racially-constructed categories (and corresponding salary scales) is to Africanise the white jobs without questioning the assumptions that underly the enormous differentials. This is of course a question that almost all ex-colonial countries have had to face, and, in incorporating the colonial manpower disparities directly into the salary structures of the independent state, have often from the outset placed many scientific and technical jobs at a salary and status disadvantage compared with jobs in the administrative service. The Report comments:

> But the emphasis on the race question should not lead us into ignoring the fact that Africanisation alone does not essentially alter these relations of production. The pattern of employment and the salary and wage structure remain largely intact even though many Africans now occupy these high salaried positions. For example in the public service the ratio between the highest paid (the Permanent Secretary) and the lowest paid (the messenger) is 1:75. It is unfortunate perhaps that in seeking to remedy the manpower situation our main concern has been to ensure that Africans reach parity with whites in this employment and salary structure. [1]

[1] (Government of Zimbabwe, Ministry of Manpower Planning and Development: National Manpower Survey 1981 vol. 1 (Harare, 1983, July p. 37))

These two examples from Zimbabwe have their counterparts in most other nations, in the sense that the local usage of apparently standard international job descriptions (such as 'technician' or 'technologist') varies enormously and usually reflects a compromise between an older local tradition about skill and knowledge, and a newer imported set of international categories, reinforced by educational and professional qualifications. The tension between the local traditions about skill and technology and the formal diploma and degree-based categories is at the heart of many of the difficulties of analysing or investing in scientific and technical manpower. But this is not just a contrast between the informally trained, on-the-job experienced technician or engineer and those formally trained in polytechnics and engineering colleges, although the substitutability of the one for the other makes it extra-ordinarily difficult to plot their separate contributions to a particular industry. (Thus, the existence of large numbers of 'engineering practicals' in Indian manufacturing industry (highly skilled and responsible maintenance and production supervisors with little or no formal technical qualification) makes it difficult to assess the industrial demand for formally educated engineering personnel). There is also a contrast between the formal qualification system as it operated in the original country of export (Britain, France, or USA for example), and the local set of negotiations about the acquisition of formal qualifications in the ex-colonial country importing these categories and labels.

That is to say that local traditions about skill and knowledge are visible not only in the informal systems of skill acquisition, but also in the heart of the formal education system itself. These local traditions are more accurately to be defined as complex negotiated agreements and assumptions about the way technical (and other) manpower is produced and utilised, and in what quantities. As such it is a highly political construct agreed to by industry, and the state's training ministries. Thus the number of formally registered apprentices in Zimbabwe, Kenya and India, for instance, reflects both a tradition about skill acquisition in these different environments, and also a negotiation between industry and the state about what proportion of the particular country's skilled manpower should be exposed to this apparently western training system. But these local political negotiations invariably alter the meaning of apprenticeship, so that shortly after the apprenticeship mode is imported (via ILO, external or national funding), its shape and operation is indigenised.

Any serious attempt therefore at analysing (let alone projecting) national manpower has to sort out the ways in which local traditions of skill (which are themselves by no means static) interact with indigenised formal education and training qualifications. This implies not so much a calculation of how many apprentices, technicians and scientists there are, but rather why and how these various skill and knowledge categories are used in different kinds of industries and public enterprises. It is likely, for instance, that there are a series of different mixes of engineering qualification in Indian manufacturing industry, reflecting India-specific use of 'engineering practicals', diploma holders, and graduate engineers. These mixes in turn affect college and polytechnic engineering enrolments, and are themselves affected by decisions on engineering enrolments in the education system. Thus, a national policy of close control on the expansion of engineering education at the degree level will itself influence the way in which graduate engineers are used by industry, commerce and the public sector, as will a policy of allowing engineering colleges to expand in response to market forces.[1]

A qualitative analysis of various types of scientific and technical work which looked at the dynamic interplay of local knowledge acquisition systems with the more formalised official qualifications would itself help to answer a number of the larger questions about innovation and technological capability which have been mentioned earlier in this paper. The following suggest themselves as areas of research that could emerge from such a focus on the utilisation of scientific and technical manpower:

1. The IIEP assumption about different skills associated with using imported technology as opposed to innovative skills linked to local technological production could itself be tested through case studies of technical skill and engineering in essentially foreign collaborations and in more autonomous technological enterprises. It seems highly likely that the skill mix associated with the particular technology in the country of origin is altered very significantly in the receiving country, but that the resulting skill and knowledge requirements reflect much more than the mere user skills needed to run machinery designed elsewhere. The final skill mix in the importing country will also incorporate that wider set of economic and political negotiations about training and work to which we have referred. These local negotiations will often result in engineers or technicians being used on the factory floor where the demands of the technology alone do not actually require them. Their presence is not then a straight forward result of technological determinism.

2. Researching the local mix of skills and engineering knowledge on the factory floor can also offer insights into questions of innovativeness, creativity and technical change with which we have been concerned. For example, it might be suggested that industries relying heavily on engineering 'practicals' might be less prone to technological change than industries with a heavy concentration of science-based graduates of polytechnic and college. It might further be explored whether the substitution of science-based manpower for hands-on experience (which

[1] (India provides an interesting case study of the federal control and subsequent opening of engineering education to popular (and political) pressure at the state level, especially in Karnataka and Maharashtra)

is going on apace in Indian industry) may be associated with any increase in product quality. Alternatively, if larger numbers of science and technology diplomates and graduates find themselves replacing 'practicals' and working in positions that only require a fraction of their science-based knowledge, this will not necessarily lead to any consciousness of product quality, especially if the enterprise as a whole has little interest in research and development.

3. In the wider debates about the impact of science and technology policies upon indigenous technological capability, case studies of particular industries and their science manpower may be valuable. What are the precise consequences of the collaborationist mode with foreign technology on the one hand and the protectionist mode on the other as far as skill and knowledge at the firm level are concerned? We have already referred to Mohan's view that the dominance of foreign collaborations directly affects the production and utilisation of scientists in India.

But over against this, as just as provocatively argued, is the view of Sanjaya Lall that the protectionist technology policy regime in India has certainly not had the effect of stimulating a dynamic or competitive indigenous technological capability.[1] It would seem that neither India's forms of foreign collaboration nor of industrial protection have acted as catalysts for innovative R & D, nor have promoted powerful backwash effects on the quality of science. But again, it looks as if rigorous research on the impact of different trade policy regimes on the science and technology environments has scarcely been done.

e) <u>Science manpower for new technologies: Science cities and science villages</u>

A final area that may be worth flagging relates to the manpower side of new technologies. This seems to be an area where there is very considerable confusion, and where very little social science research has been addressed to the choices and decisions facing developing and industrialising countries. The lure of the new technologies (genetic engineering, biotechnology, microelectronic applications, for example) raises in a new and urgent form many of the issues that have been discussed earlier, not least the question of indigenous knowledge, selectivity, comparative advantage, and relevance to the mass of people living in rural areas.

There is however something of a tension between the science-for-all perspective associated with the more traditional science popularisations campaigns of many countries and the new-technologies-for-all message that is becoming increasingly commonplace.

[1] Sanjaya Lall, 'India's technological capacity: effects of trade, industrial and science and technology policies' in K. King and M. Fransman, op.cit., p. 238-241)

In the former, it is expected that science-based messages about health, agriculture, family size, etc. will be able to displace so called 'unscientific attitudes', and gradually transform village life. The outcome might be termed a 'low level scientific temper', improving yields gradually, reducing family size as family income grows. At the same time however what may be called 'high technology scientific temper' (or tempter?) suggests that these same goals can be achieved and the quality of life and work much more fundamentally and rapidly transformed by introduction of newer new technologies.

Some of the literature on the importance of these new technologies in relation to developing countries shares the rhetoric about leapfrogging the slower agricultural and industrial revolutions of Europe which was so commonplace in the 1960s; but they often go beyond even that optimism to expect qualitatively different experiences for communities exposed to new information and other technologies. The extreme form of this transformationist thinking can be seen in the current experiment to saturate with French microcomputers a simple village in Senegal to see if some cognitive frogging will result. But there are plenty illustrations in other countries where the allure of new technologies beckons to the science and technology planner, and even to the education planner. Thus, educational technology which had emerged from the 1960s and 1970s battered if not defeated by the signal failures of educational TV in the Ivory Coast, Niger and elsewhere, enters the 1980s with the bright new armour of computer literacy, VCRs, computer conferencing for schools and much more. These are marketed not any longer as educational aids or extras, but as instruments that will dramatically change the cognitive experience of children. When ministries of education in developing countries hear tell of the hoped-for qualitative changes in the child-power of OECD countries, it must be extraordinarily hard not to order up the same machinery. Typical of the new information technology literature on the impact on schools is the following:

> unprecedented changes could indeed take place affecting the following sectors:
>
> (i) Learning processes could be changed and school children much earlier acquire certain logical structures and formal and conceptual skills currently developed only at later school ages. It is also likely that they would learn different skills and build different knowledge systems in ways which we are only beginning to perceive.
>
> (ii) Curricula could be radically remodelled.
>
> (iii) The individualisation of education offered by interactive NIT* *could turn over the very structures* of the institutions concerned. 1

[1] (OECD, International Conference on Education and New Information Technologies, mimeo, 1983 p. 2 emphasis added).

*New Information Technologies

Nor is NIT seen in the OECD context as an occasional 'micro' in a secondary school, but as a highly complex interactive learning style with some or all of the following components:

> The New Information Technology .. are computers, videotex, cables and fibre optics and satelites and computers in conjunction with traditional or new audio-visual technologies. There is already a tendency towards interactive multi-media systems combining sound and picture, all under computer and particularly micro-computer control.[1]

This is heady stuff for educationists, in what has always been regarded as one of the most labour-intensive service sectors. But in other sectors and ministeries, equally compelling applications of microelectronics and other technologies make it hard to be selective. The new information technology order appears like a seamless web; it must be bought as a package or not at all. Also unlike the engineering technologies of yester year, there is a distinct sense that tomorrow may be too late to join a race where ten years covers more ground than a hundred in the older technologies.

At the international level, the United Nations Advisory Committee on Science and Technology for Development have been arguing for the integration of these new technologies with traditional technologies. Again, the logic of transforming traditional technologies with new applications is compelling. Over against the thirty or forty years of promoting gradual change through appropriate technologies, the new disciplines beckon with offers to increase productivity, transform quality, and somehow catapult the idiosyncrasy of artisanal products into world markets previously denied them. A document worth examining as representative of this trend is that on Integrated Application of Emerging and Traditional Technologies for Development.[2] The starting point for its discussion is the assumption that 'prospects of technological innovation, particularly in micro-electronics, biotechnology, communications and satellite technologies, are changing life styles and development patterns in developed and developing countries'. In each major sector, examples are held out of ways in which these new information-based sciences are transforming the potential of developing countries.

A very rich example of the vistas that open up in this kind of literature refers to possibilities in agriculture, medicine and biology. Each sentence points to a new disciplinary era, but by the end of the passage, the link to traditional technologies is a little thin:

> Some modern technologies have been successfully used to upgrade traditional methodologies. For example, the International Rice Research Institute is successfully utilising various traditional and new technologies, including a large computer system, to accelerate the pace of

[1] (OECD, International Conference on Education and New Information Technologies, mimeo, 1983 p. 2)

[2] (Integrated Application of Emerging and Traditional Technologies for Development, International Rice Research Institute, Laguna Philippines, 1982)

> of progress in rice research. Other examples are remote sensing for land and resource assessment, development and application of environmental monitoring and computer use for correlation analysis between crop growth and climatic conditions and crop disease epidemic forecasting.
>
> It is now generally recognised that emerging biotechnological developments in areas such as tissue culture, genetic engineering, and monoclonal antibody techniques are opening new horizons for application in different biological fields. Atomic energy and tissue culture are being utilised to speed plant research and develop new crop varieties.[1]

All the topical areas of new technology are mentioned-remote sensing, environmental monitoring and computer modelling, genetic engineering, biotechnological research, but little is said about the mediation of this new knowledge from those countries which currently possess it to LDC research centres and it turn from LDC centres to the present users of traditional technologies in the villages and towns. There are serious manpower issues to be discussed at both stages of this knowledge production and dissemination in LDCs. Not least there is the problem of getting behind the loose images of applying these new technologies to traditional technologies. Is, for example, the design and development of new technology products to be done in the huge research laboratories of the West and only the finished products to be made available to LDC researchers and farmers, or can an industrialising LDC readily replicate the research culture of these new technology laboratories, with their close links to multinational capital?[2]

The upgrading of traditional technologies by the application of new scientific knowledge (if not of the newer new technologies), is an area where India has had much experience. Most of them have involved a lengthy dialogue between modern research scientists and villagers, usually in a single village or pilot site. The process has been highly labour intensive and the success in injecting new science-based techniques into traditional technologies has been restricted very often to a single pilot village and to one or two crafts. Whether the village has been associated with an IIT, with ASTRA, NISTADS, or with the dedication of individual scientists who have located in villages, the mix has been similar, the replication a problem. But the spread of low technology scientific temper has always at its best assumed that there could be a profitable dialogue between modern scientist and traditional craftsman.[3] By contrast, the newer proposed integration of traditional and new technologies discussed in the development literature of the UN and elsewhere will almost by definition have no room for dialogue with the present producers.

[1] (Integrated Application of Emerging and Traditional Technologies for Development, International Rice Research Institute, Laguna Philippines, 1982 p. 7 emphasis added)

[2] (For an Indian critique of these possibilities, see Praful Bidwai 'The seamy side of the Gene business', Times of India, Nov. 21, 1983 p.8)

[3] (For a very recent example see CSIR S & T Field Station at Bankura(West Bengal) Project: Village Artisans and Science: a Profile, Nistads, CSIR, New Delhi, 1983)

Although aimed specifically at the small scale informal sector operators in rural and urban areas, the following agenda seems just a little remote from the realities of petty production in the unorganised sector of the economy:

> The Group identified the following emerging technologies as offering scope for integration with traditional technologies: communication, computer, and information technologies including satellite application; microelectronics in areas such as computer aided design and manufacture and numerically controlled machines (robotics), office automation, etc.; mini-factories with self-monitoring, self-diagnosing microprocessors; new materials, including lasers, polymers, ceramics, new sensors, and optical fibres; and new energy technologies for harnessing, processing, distribution and efficient use of solar, geothermal and biomass power, etc.[1]

Just in case this may give the impression that all will be swept away in the application of new information technology to village life, the report admits that there may still be a place for a few old-style artisans:

> Some traditional manufacturing technologies must be maintained to use local skills. Developing countries <u>may</u> need to preserve traditional industries and artistic production, such as batik and woodcarving, that do not suffer competition from modern technology.[2]

We have suggested that in the heady language of computer applications to traditional technologies, the training and manpower issues get neglected, or rather the impression is created that the new technologies somehow incorporate and transform the villager almost without training, as older technologies have never done. In the newspeak of new information technology therefore, the villagers with their village level micros begin accessing world knowledge on specific development problems of their community. Within seconds an interactive dialogue is underway, preferably via satellite, and the 'distinct receiver demand' articulated and answered. The communication process is itself the training. In a remarkable passage in this newspeak of interactive communication the UN Advisory Committee discusses what is left of the training dimension in this new information technology order. It deserves quotation at some length:

> Institution builders with capabilities to organise research and development, formulate policy and strategy, and develop and implement projects and programs must be trained. Specialists with specialised knowledge in traditional and emerging technologies who have multidisciplinary competence

[1] (United Nations Advisory Committee, <u>Integrated Application</u> op.cit. p.9)
[2] (IBID p.9)

and social awareness must be taught to lead research and development projects. Developers must be organised into mobile productive systems and communicators must be included in projects to build bridges between users and innovators as well as between research workers and policy makers. Technicians, artisans and others must be encouraged to spread the knowledge downstream and bring problems upstream for technology development. Utilisation of emerging communications technology and software development for this purpose will carry messages to the community.

Developing nations could selectively draw upon expatriate nationals who are working abroad, expecially in the areas of emerging and high technologies, to bring about development of integrated technologies and human resources.

Human resources development at the grass roots level and for upstream flow requires a different approach. Normally, the introduction of new techniques and technologies is easiest when preceded by a distinct receiver demand articulation.[1]

For the social scientist concerned with the interaction of science, development theory and human resource implications, the world of new technology and the related negotiations about the terms on which it enters the traditional domains of the school, the farm, the factory and the office, should be high on the research agenda. In many developing countries, decisions are being taken in relation to information technology for development in every sector from computer literacy in schools to office technology, and even where decisions are not explicitly taken, developments occur by default. There may appear to be a catch 22 aspect to social science analysis of these developments, since it could be argued that until the new technologies are in place, their social impact cannot be evaluated, but once they are in place, it is too late for social scientists to have any influence on the decisions.

In this respect it seems essential for some Third World researchers to be examining the development of the new technologies in the industrial heartlands of the North, in the same way as we have mentioned the necessity of understanding the implications for skill in the South of technical changes in the North. There is fast becoming available critical work on the social and political aspects of new information technology, but this work in the North is submerged by the mass of advocacy writing on NIT. It seems highly appropriate for instance for the groups associated with Science for People in the UK and parallel publications in the USA to be known to social scientists concerned with People's Science in India and elsewhere, and vice versa.[2]

[1] (United Nations Advisory Committee, Integrated Application op.cit. p. 12-13, emphasis added)

[2] (See the critique of New Information Technology in Science for People, winter 1982 p. 12-20)

Anil Agarwal of the Centre for Science and Environment has made a similar point about the need for South-North communication if social scientists are to be able readily to monitor and critique developments in their own country, and has underlined forcefully the structural problems in maintaining open access:

> An enormous amount of research of relevance to developing countries is taking place in developed countries. For instance, research work on malaria vaccine is not being undertaken in any of the malarious countries..but in places like Paris, London and New York. The work in the international agricultural research institutes has an enormous impact on national agricultural research systems. But given the fact that information bases in Third World countries are still so under-developed, it is not always possible to talk to someone locally (as a journalist would do in London) about the details of, say, the Brazilian alcohol programme to replace petrol. Travel to a foreign country is inordinately expensive for a Third World journalist, often even 15 times more expensive than his/her counterpart in a developed country.[1]

The same applies just as powerfully if not more so to social scientists, and scientists in the Third World.

Conclusion

We have attempted to suggest in this brief review of selected national and international literature on technology, science manpower and education that there are significant benefits likely to accrue to an interdisciplinary approach to many of the issues in these areas. This is particularly appropriate since so many of the groups, centres, ministries and international bodies proposing science-based action have an explicit or implicit education dimension for their intervention. Equally, the education investment activities whether in computer literacy, quality in science at the college level, or skill acquisition for artisans in the unorganised sector, all make certain assumptions about the utilisation of the science and technology courses in society. Frequently these assumptions are not thought through, nor their implications at all clear; on other occasions, as with the apparent planning of engineering or medical places at university, the rationale is as much the result of a political negotiation as a technical or economic calculation.

More generally we have noted that there are several competing advocacy positions involving science and technology, and much debate about relationships between western science and education

[1](Anil Agarwal, 'Science in our daily lives', Advisory Committee on Science and Technology for Development, April 1983, mimeo, p. 33)

and local skill and knowledge systems, and in turn between westernised local skill and knowledge on the one hand and indigenised western norms and traditions in science and education on the other. Assumptions about how the modern relates to the traditional, and the newer to the new, are extremely varied, and frequently unexamined. India, however, already has a very rich strain of work relating to the philosophy and sociology of science; this has gone far in sorting out the different science colonialisms and indigeneities, the clashes both within the knowledge systems of the exporters and the recipients, and the dynamic interactions between the sciences of Europe and of India. The historical depth of much of this analysis of sciences in India has been one of its greatest strengths, and is an essential element in counterbalancing much of the international development literature on these themes, whose time horizon is seldom further back than the 1970s. The debates therefore about new information technology and science cities today can be built on a long and distinguished set of concerns about science, technology and education relationships in India.

So, as the Science Congress in West Bengal in 1984 calls amongst much else for investment in quality science through a chain of institutions for the gifted from nursery to college, and for special privileges to be attached to the instructors in this new network, it is valuable on the one hand to have available in India both a science-for-all rationale that is older than UNESCO, and a searing critique of the magic of education investment for industrial transformation that precedes the era of manpower planning, and is a useful counterpoint to Kenya's science rhetoric with which this paper started. Prafula Ray, the early Bengali chemist-cum-industrialist writes of the inter-war years:

> I had to point out how most absurd and fantastic notions are entertained by our countrymen on the capability of a Technical Institute. Our Universities and Educational Institutions in general impart education which, it is urged, is too much of a literary character; all that you have to do is to substitute technical for literary instruction, and industries will spring up magically all around.
>
> Sir M. Visweswaraya's passionate plea for the creation of a Technological University is based upon this obsession.....
>
> Never was a greater delusion entertained. In every country, industrial progress has preceded progress in science and technology.[1]

[1] (P.C. Ray, Autobiography of a Bengali Chemist, Calcutta 1958 p. 262)