Science, Technology and Education Research in India

A Discussion Paper

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SCIENCE, TECHNOLOGY AND EDUCATION RESEARCH
IN INDIA: A DISCUSSION PAPER

Introduction:

Even a few days of listening, reading and talking in India can throw up a host of issues related to science, technology and education (STE). Concerns about STE are clearly very near the surface. Within this short period(1) there have appeared: (1) the latest controversy in a round of intense debates about Nehru's plea for "scientific temper"; (2) an attempt at a national level to prevent some engineering colleges from charging up to 10,000 dollars as capitation fee - so fierce is the competition to enter the prestige science and engineering sector; (3) a twenty page feature in Business India on the Indian Institutes of Management (IIM), covering all the issues that emerge whenever prestige training and Indian industry are examined: brain -drain to US industry, student disenchantment with "managing" rural development and social welfare, creativity and its lack; discrimination in admissions policy, and the role of liberal education in the ordinary university sector.

Without prompting, the intellectual community and policy makers on science and education planning link the alleged malaise to a combination of structural and educational factors. The world's third largest stock of scientifically-educated manpower is frequently caricatured for being mediocre, unable to compete internationally, and having no particular comparative advantage. In almost exact parallel, the products of industry itself are equally criticised; they are mass-produced like the products of the education system, and like the latter they lack quality and finish. The pass mark in the school leaving examinations is 35%, and the poorest colleges will accept students at this "pass"level. Similarly, weak quality control allows goods into circulation that are very poorly finished. Quality control is set very low, and the general image of industry is of low standards, and of a lack of concern with international competitiveness. Of course both education and industry are more differentiated than that. They combine relatively small "elite" sectors which seek to remain on the gold standard (for example, TATA enterprises and the Indian Institutes of Technology (IIT))along with a mass sector that has allegedly gone off the international standard.

Paradoxically, India has done what many other Third World countries are berated for not having done. She has in general not tied her school and college standards to some high cost western benchmark, and consequently is able to offer many of her people some of the cheapest school and and college education anywhere in the world. In parallel, where Indian industry is most internally competitive, there is the possibility of purchasing an enormous range of goods at very low cost, even if of very variable quality.

No one doubts that the patients (education and industry) are very much alive. Indeed they both demonstrate a frenzy of activity. The worry rather is about content and direction. There is a desire on the one hand for an internationally competitive scientific research community and a similarly export and quality oriented industrial sector. But this coexists with the view that Indian science (and by extension, Indian industry) is in reality a sea of mediocrity, and that somehow this failure to be

(1) July, 1982

innovative and to produce quality products is education-based. Analysts know only too well that, to an extent, colonial education deliberately excluded the quest for innovation and creativity (engineering college syllabuses, for example, were organized around maintenance rather than design work). But in the 35 years of independence, the desire for industrial and scientific autonomy has been somewhat inadequately fulfilled by the school and college system. Dinesh Mohan of IIT Delhi implicates the school system quite directly:

> One cause of mediocrity at the college level is that we seem to have expanded our post-secondary capacity very fast without inculcating the scientific temper in our primary and secondary schools. Education for the student, all too often, is instead an exercise in memorising information uncritically, for its own sake. We have failed to make quality education available to the majority of India's children (Mohan, Seminar Feb. '81, p.6)

On the other hand, despite not being internationally competitive, Indian scientific capacity for all its numbers has allegedly made little dent on the mass problems of poverty, disease, drought and energy. The "Statement on Scientific Temper" drawn up by twenty leading scientists and widely publicised since July 1981 made the point very starkly:

> We have all the technology available right now within the country to give water, food, shelter, and basic health care to our millions. And yet we do not. Something has gone wrong. (Mainstream, July 25, 1981, p.7).

In sympathy with this conclusion, but reaching it from a very wide spectrum of political philosophies, are any number of organizations, voluntary societies and individuals who have sought to make science a much more powerful and popular vehicle of development. Indian science despite not attracting accolades internationally does not apparently even have the satisfaction of having taken itself to the people. This failing is the spark for a host of almost uncoordinated attempts to bridge the gap between scientific knowledge and poverty. Some use the formal school, some non-formal education with adults. Some treat "science" as a weapon of awakening as Freire treated "Literacy". Villages are adopted to prove the value of applying relatively high technology to village backwardness, others to demonstrate that the scientific improvement of traditional technology is the way forward. A mass movement for people's science in Kerala vies with young scientists who have left the cities to work with one subdistrict, or with one scientist trying to run a personal primary school exposing just ten children to scientific methods.

The scientific apparatus is equally varied. Overhead, the Indian satellite will from August 1982 use "high" technology to get development films to a certain number of states with receptors supplied. Elsewhere simple primary science kits in plastic bottles with 30 experiments emerge from the science education centre named after one of India's most famous nuclear scientists, Bhabha. Elsewhere again physics, chemistry and biology are taught without a lab, and without any materials for practicals at all. Yet physics, chemistry, biology and maths are all compulsory up to grade X, the school leaving certificate.

Lower down the training and industrial systems, India has massive resources of skilled people, some in traditional handicrafts, some in the modern sector. In industry in particular, the tradition of developing skills on the job is firmly entrenched, and a whole system alternative to formal training exists for producing/roughly equivalent /people to skilled worker, technician and engineer. The latter, termed "engineering practical", underlines a further point that is part of this complex interaction of skill, technology and education. There is a widespread feeling that trained people do not work in fields they are trained for. Engineers work as inspectors, supervisors or on sales or marketing because the less formally trained "engineering practicals" take their place. At the apex of the engineering training system in the IITs, a significant number after graduating go straight to the other apex institutions for management training (IIMs) and thus become managers rather than engineers. The system whereby a large group of the same people get both the best engineering and the best management training has been termed "gold-plating gold."[1] By contrast, the whole routine maintenance sector, from cars, to phones, to buildings and electrical machinery is serviced by people with few formal skills, and who, moreover, are seldom likely to possess any of the products they are said so inefficiently to be maintaining.

This enormous informal alternative sector in Indian industry, and its learning and training methods are clearly another ingredient in the mix of factors leading to indifferent quality in industry, and to the non-utilisation of the formally trained in the positions suggested by their diplomas and degrees.

The last set of factors that relate to the whole discussion about science, technology and education is the question of foreign collaboration, industrial self-reliance, imports and protection. Unlike most countries in the South or North (with the possible exception of Russia and China) almost everything openly available for sale has been made in India, most of it on machines made in India, but a very high proportion of the electrical and mechanical items were originally made through a foreign collaboration and in many cases continue to be. Despite the high collaborative element, quality has remained a problem, as has the alleged continued dependence on foreign collaboration. It is further widely argued that "there is hardly any science-based innovation in Indian industry" (Mohan op. cit. p.6).

It can be seen that many of the same issues reappear in different arrangements in many of the areas centrally affecting science, technology and education. Some of these will be examined at greater depth, to give an indication of the many action research areas already covered, as well as some which are only beginning to attract serious attention:

1. Issues relating to the quality of science education in the formal sector.
2. Research accumulation on non-formal science education.
3. Utilization of science manpower.
4. Changing ideologies of science and technology.

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(1) Business India, July 5-18, 1982, p.54

1. Quality of Science Education in the Formal Sector

At one level, science is better established in the school system of many Indian states than is the case in other countries, including some in Europe. Science through environmental studies commences from Grade I; in the upper primary school, science is disaggregated into disciplines of physics, chemistry, biology and maths, and in the high school it remains compulsory until Grade X. The pattern will change somewhat from state to state, but the common thread is a strong science emphasis. Common also is a resistance on political grounds to devising one curriculum for stronger students, and one for the less academic. Professional educators may be attracted by differentiation, but not so the policy makers. Not surprisingly, the pass mark at school leaving certificate (SLC) is kept low (35% for maths and science subjects) and even then rather less than 50% pass. Even in the highly educated (and some would say science-motivated) Kerala State some 350,000 are taking the SLC for the first time in any year, while a similar number are repeating.

A good deal is known in general about the examination-orientation of much Indian education, but how this affects particular subjects in science, and how far the backwash of SLC washes down the school system is not known. If there is a role for schools and colleges in producing this scientific temper, then presumably the teaching and learning environments for science become important. In resource-poor schools, without labs, there may be enough material for the teacher to demonstrate, even if no student can personally experiment. In other schools, completely without science materials, science subjects presumably become like maths, or history, taught entirely from the blackboard and textbook. Science is then learnt free of any practical experience. Even in better endowed schools, practicals in science are frequently squeezed out by the mass of theoretical material in the four science subjects.

The way that science is first acquired may seem a far cry from the larger questions of quality and innovativeness of industrial research but it is widely felt that if science education is to become a questioning attitude of mind, then it cannot easily be acquired in an education system that "works in an atmosphere of conformity, non-questioning and obedience to authority"[1]. It is for this reason that the Kerala Science Movement (Kerala Sastra Sahitya Parishat - KSSP) since 1971 has been taking science education into the schools with popular publications for different age groups, developing also several thousand science clubs and science corners, and promoting quiz competitions across the state. This voluntary association has a whole non-formal adult science education wing, as will be seen later, but in schools alone their impact has been presumably an important supplement to the regular curriculum. According to one teacher, his science club allows the children to ask questions which there is no time for in class. More important, the KSSP begins to put across to children the idea that science is not about formulae but about the application of knowledge to socio-economic problems.

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(1) "A statement on scientific temper", Mainstream, July 25, '81 p.7

Action and Research in Science Education

Apart from the KSSP, there have been a series of other bodies concerned with the improvement of science education in schools. Most of these accept that the explosion of new knowledge makes science education even more critical in schools; they are equally aware that science teaching generally is a parody of scientific method. The emphasis is on more and more information correctly remembered, and ideally quoted from the textbooks. The very goal of promoting more science can thus be counter-productive. Whole sections of science knowledge are pushed further and further down the school system; concepts once taught in higher secondary are introduced in the primary school.The overloaded science syllabus then requires more traditional teaching and memorisation; it is difficult to justify time on experimentation and discovery. Hence the increasingly academic status of science in schools.

Different approaches to this oppressive teaching of science have been tried over the last 15 years, particularly during the 1970s and most have sought to reinstate the importance of discovery, observation, and independent judgement. Methodologies have included the use of kits, materials development, simplification of language, teacher orientation, national talent searches, science fairs, science centres etc. In general, and perhaps inevitably, these activities of intervention and change have not been very carefully monitored; the process of adding up what has been learnt in a decade and more of experimentation is just beginning. It may be useful therefore to give some indications of where reflection upon action would be particularly valuable to the science community in India and to its counterparts in other countries.

Homi Bhabha Centre for Science Education

Tata Institute of Fundamental Research (TIFR). Spun off from TIFR in 1974, the Centre institutionalised several years of voluntary work by TIFR scientists in the Bombay Municipal school system. It was now possible to innovate and experiment in science education with the advantage of the TIFR research base. Understandably, this centre's work has been particularly concerned with the evaluation of its activities. Broadly, these have included a series of materials dealing with scientific problems raised by children, a set of concerns with simplifying the language of science, action research projects in providing discovery science to first generation learners in the rural area of Khiroda in Maharashtra, supplementary (Saturday) science for backward caste children from Bombay secondary schools. The last activity emphasises all the aspects that are missing in traditional science teaching and in pupils' attitudes, but beyond the problems of science education in general has the additional aim of giving the scheduled caste children the self confidence that they can succeed on merit. (One of the problems of the national government's policy of quotas and reservations for scheduled caste and scheduled tribe students, and the practice of allowing their entry to institutions at much lower grade scores than the other students is precisely the damage done to their self confidence). By contrast the Homi Bhabha centre wants to show that with the little supplementation (2/3 hours a week for 2 years), promising students can adopt a qualitatively different approach to learning. A second wave of students has now started the same 2 year program and this time there is a control group of equally bright students not attending the centre. As anticipated, exposure to the Homi Bhabha "system" does make a significant difference in their ordinary end of year exam scores, as well as to their attitudes to learning. Sceptics would argue that weekly contact with talented and committed research scientists, intent on question-raising and personal experimentation, is bound to have an impact, but how can it be generalised, how can it stop being the personal tuition experience of 30 selected students, and affect the schools from which they are drawn?

The centre can defend this action of experiment on a variety of grounds: it offers directly relevant policy research on equalising opportunities for scheduled caste students. It feeds directly into materials improvement for secondary school students. It also acts as an inhouse lab for examining processes of change. There is finally the possibility of continuing with a longitudinal study as the pupils leave school for higher education and the labour market.

The centre's wider concern with educational measures to counter social deprivation has led to their search for relatively low cost changes with high pay-off. One of the most attractive of these has been the production of an alternative set of science books for Marathi speakers from grades V to VII. Everything was held constant in the new texts - identical pictures, pagination, etc. to the government textbooks -- but the language was dramatically simplified. Results were very encouraging; increases in mastery were evident, but decreases in the tendency to memorise passages, which so often affects student learning. Pupil and teacher participation also improved noticeably. Persuaded by these initial findings Bombay Municipal Corporation has encouraged a much more comprehensive trial of these simplified science texts(1).

The Homi Bhabha centre illustrates the range of different action research approaches to specific and general problems of improving science education. Materials development: but how to get them into schools. Discovery learning: but how to spread it beyond the range of the centre's influence. Moving from micro to macro has been attempted in the centre's Khiroda experiment where many of the centre's strategies were applied to a rural school network and further materials developed. From available documentation, this pilot extension of the centre's methods seems to have worked out well between 1975 and 1977. The hope had been then to move to implementation on a large scale, and it was assumed that the personal contact as a means of communication would have to be replaced by modern technology of mass communication. (2) This has not happened but we will notice later the potential of INSAT, the Indian satellite launched on April 10 1982 as a possible follower of educational work under the 1975/6 SITE satellite program.

Science Education via Science Kit

A natural response to the lack of any equipment in most schools,

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(1) V.G. Kulkarni and V.G. Gambhir, Homi Bhabha Centre for Science Education, "Effect of Language Barrier on the Universalisation of Education" Indian Educational Review, Jan. 1981. pp.48-59

(2) Proceedings of the Conference on Science Education, Khiroda, Jan. 17-19, 1978, TIFR, Bombay

and the consequent teaching of science as an entirely academic subject has been the development of science kits. The attraction of putting together a set of teaching aids in a portable container encouraged UNICEF and the National Council for Educational Research and Training (NCERT) from 1972 to promote India-wide kits and supporting guides. At the state level these have been made at relatively low cost (and ease) compared with many other Third World countries, and with some variations from state to state have found their way into primary schools. In Gujerat, for instance, a single kit box for St. I to St. IV went out to each of the state's 30,000 odd primary schools free, and for standards V, VI and VII, kit boxes were also developed and sold with differing degrees of state and district level support.

Kit boxes have not been given out in isolation from support activities. Indeed as part of their support to science education, UNICEF encouraged the establishment of science education units in the State Institutes of Education, and these in turn then ran a whole paraphenalia of courses -- for science teachers in teacher training courses, for science inspectors at the district level, for lab assistants in colleges, and also kit box courses for primary school teachers themselves. No less than 25,000 of the latter had been exposed to those 3 day courses since 1972. But what is known of the impact of these state wide initiatives with science kits? Very little.

Preliminary inquiries in Gujerat State for instance reveal that kits on arriving in schools are entered on what is termed appropriately the Dead Stock Register. This is annually inspected, and should anything entered there be lost or broken, the procedure for removing it from the dead stock register must be initiated. The complexity of this bureaucratic procedure is such that few headmasters or teachers would willingly embark upon it (for articles lost costing more than 10 dollars, a whole committee has to be set up at the district level to make recommendations). In consequence, the kit box is better preserved locked and ready for inspection.

Kit boxes are a good example of the problems of curriculum innovation in sciences. Even if teachers are allowed to use them, they are only a partial answer to the problem of doing rather than learning science. At best, in a class of 40 or 50, the teacher may demonstrate something, but the pupils will not be much nearer trying things out for themselves. So even if the obstacle of the dead stock register is overturned, there still remains the question of access and personal observation.

One of the most original attempts to work with kits and still make all pupils participate has been that associated with Hari Parameswaran and the Dynam Engineering Corporation of Bangalore. Ten years of trying to market low cost science kits to schools have brought the conviction that one kit per school is really not worth fighting for. It cannot be replaced, it cannot be shared, or experienced. After abortive attempts to market kits to 26,000 schools, and intensive interviews with all kinds of teachers, Parmeswaran now runs a "teacher proof" use of science kits, in the sense that he has his own cadre of 26 teachers, who are dedicated experimental science teachers. In schools that agree to take the programme (at 5 rupees (50 cts), per pupil per week, they will offer a weekly exposure during a double period of activity methods. For this price, all children will have access to cheap microscopes or whatever materials are necessary. The children's regular teacher will sit in, and insure coordination between the live science program and the regular syllabus.

There is as yet no evaluation of the program, but the following points may be made. There is a built in advantage of the same agency organizing the teaching and producing the kits. It is possible to have rapid feedback from the schools and make modifications and explanations to the kits and literature that a purely commercial operation would not be interested in. Live science can be organized as a supplement to regular science teaching through an itinerant teacher corps (just as it can on Saturday afternoons at the Homi Bhabha Centre), but ultimately Parameswaran would need to retrain the regular science teachers if the scheme was to move beyond the schools currently involved. Finally, because of the cost factor, the present schools are largely those which, though overacademic, really need the supplementation the least. Poorer municipal schools cannot pay for the program unless there is an official subsidy.

At the moment India has probably got a wider experience of different kinds of science kits than many other countries. In addition to those mentioned, there is a science-kit-in-a-jar produced by Homi Bhabha and intended to make possible 30 basic experiments. At the other end of the market there is an electronics kit produced in Madras by the Committee on Science and Technology in Developing Countries (COSTED), and distributed to colleges and schools. It would be very timely to try and pull together what has been learnt in all these separate initiatives. Such has been the importance of UNICEF support that a separate analysis of its program via NCERT should probably be undertaken. Equally, some detailed work needs to be undertaken that examines the interaction of teaching aids (such as kits) with the syllabus in ordinary primary and secondary schools. What kind of science understanding can there be in a 2 teacher village school, where the presence or absence of a science kit is the least of the school's problems? No sanitation, no electricity, little or no equipment, pyramidal drop-out pattern etc. The inventiveness associated with kits is hard to visualise in the absence of much more basic infrastructures.

Community Science Centre, Ahmedabad

Kits and curriculum materials are two ways of attempting to bring science alive. We have noticed in their application to the school system a tension between "adding-on" live science and installing it directly in the regular curriculum. Inevitably community science centres (and science museums) will be more on the enrichment-supplementation side of the spectrum. This is true of the CSC in Ahmedabad, one of India's most distinguished attempts to make discovery science influence local schools and the local community. Here too despite 16 years of very rich experience, there seems to be little comprehensive analysis of the lessons that have been learned. Yet some account of the diverse action in curriculum development, programmes for motivated students and teachers in lab work, and the more

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recent moves into non-formal education in rural areas would be very valuable. Of course much of this is available in annual reports, and in the occasional evaluation report of a particular activity, but a more synthetic account of a decade and a half's attempt to influence local schools, teachers and textbooks would be useful.

Each CSC unit has an institutional memory of trying certain approaches, working with students / teachers, both in a targeted /and and in an open house fashion. The same tension noted earlier inevitably appears: if promoting discovery approaches to science, do you narrow the discovery to illustrating particular problems in the actual syllabus of different grades, or do you develop non-syllabus specific exercises in observing, doing or questioning? Years of doing the latter may mean almost no dissemination of materials painstakingly developed. The former draws the centre into the narrowness of "experiments for 5th graders". This last is particularly problematic if the very basis of the 5th grade syllabus has little intellectual justification.

As with the Homi Bhabha Centre, part of the rationalisation for having small groups of St. V, VII, or post-graduate students utilising the CSC labs on a weekly basis must be to extract from those motivated students insights, problems and procedures that can be made the basis for new curricular materials, or new orientation courses for teachers. But what has been the experience with teachers? That only 3 out of a group will be sufficiently motivated to put CSC ideas into practice? What about supplementary materials for children? Will children really read booklets that are 100% or even 30% science information? What is the experience of Kerala's KSSP with its 35,000 circulation of EUREKA[1] to children in primary school?

At least one member of CSC's staff, Jayashree Mehta, is worried about the tendency for action to push out reflection. Her three years of weekly visits to a rural school to teach and monitor science have led to major questions about the kind of concepts children can deal with in upper primary school. Is there perhaps a need for more basic research related to the reality of rural primary science? Perhaps partly in acknowledgement of the difficulty of making rapid progress with the formal school, the centre has diversified towards non-formal education, and is developing programmes in nutrition and health education for rural functionaries (with the help of CARE, and then USAID). Attractive as these new activities are, there is a continuing obligation to work with schools and colleges, and hence a need to consider what has proved possible and what not feasible amongst the demanding objectives set forth in 1966. For example

> "1. to promote among students, teachers and the lay public (a) an understanding of fundamental concepts involved in the physical and biological sciences and mathematics (b) the acquisition of scientific knowledge and insights as far as possible by the process of inquiry through experiments, AV media, and other means ------- 4 to help make clear the social implications of science and technology.

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(1) Science magazine for primary age children

Kishore Bharati and Friends Rural Centre, Rasulia, Hoshangabad, Madhya Pradesh

These organizations have just completed a decade of action and research for the improvement of science education in middle schools. Faced with the familiar problems of memorised science, the increased quantum of information in textbooks, and the rural-urban school communication gap little appreciated by curriculum planners, the Hoshangabad Science Teaching Programme (HSTP) aimed to introduce discovery science in ordinary government middle schools. Starting with 16 schools in 1972, it encompassed all 220 middle schools in the district from 1978. It has recently reflected on some of the major achievements and existing limitations of this programme. (1) On the credit side, the workers feel that they have demonstrated that innovation is possible in government educational structures, and that joint voluntary agency-government initiatives are one way of implementing changes that neither might achieve on its own. A really large cadre of teachers can become committed to the new approach of teaching science by discovery methods, experiments and field trips. A crucial element in the mix has been the commitment of high quality research scientists from TIFR, IIT, UGC, Delhi University, and other universities and colleges in this science-based improvement of village education.

On the debit side, the major limitation "concerns the attitude of the government. Barring some motivated government officials at senior and junior levels, the general government attitude has been of apathy and unconcern. The rigidity of administrative structures tends to reduce creative efforts to naught and considerable inputs are required to overcome such barriers". The point is made very forcibly that counter-balancing the bureaucratic structures of government really requires very major capabilities and human resources on the side of any voluntary agency. This is an issue that will be encountered again when the problem of taking "science" to the community is examined.

For the moment, one of the most significant outcomes of Kishore Bharati's reflection on its past experience is the decision to explore further areas of expansion-to carry the science programme beyond the district to the state, and to other states if there is interest. It is also apparent that there is now a concern about transferring the specifically science education methods to all other subjects and school levels. This is itself an interesting comment, for science has thus far attracted much more innovatory attention than other subjects.

The vehicle for extending the scope of the last 10 years' work

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(1) Evolving Systems for the Introduction and Diffusion of Educational Innovations: Micro level Experiments to Macro level action (Kishore Bharati, Hoshangabad, M.P. 1982)

is to be an Institute for Educational Research and Innovative Action which will have a coordination and planning centre in Bhopal and four field centres. It expects to draw its support from three sources, state government, central government, and private agencies, and for the first 3 years they have worked out a rather demanding program. A major task to facilitate this expansion programme is "a comprehensive manual in which our experiences, methodology, working methods, examination method, etc. are distilled"(1). Such an analysis would not only be very timely for focussing attention on the science education system; it would also be concerned to pinpoint processes that allow the diffusion of micro experimental schemes into macro level action programmes. The transition from micro to macro has been the reef on which most innovative action has foundered.

> Creating a few model schools and universities (Sevagram and Shantiniketan come to mind easily) is in the wider context quite meaningless as the beneficiary populace is not even a countable fraction (2).

The above four institutions (Homi Bhabha, CSC, Parameswaran's science kits, and HSTP) were selected in no particularly scientific manner to illustrate something of the state of research and action in science education over the last decade and more. Doubtless, it would have been just as easy to select other agencies (3), and reach some similar conclusions about the current climate of science research as it impacts on the formal system.

We have noted a strong and growing interest in adding up what has been learnt in this decade, and also other areas where it is more difficult to pinpoint research-based conclusions. A partial listing of areas that would benefit from further review and research attention would include:

(i) Qualitative studies on how science is actually taught in primary and secondary schools and colleges. It is widely assumed that the present methods are/travesty, and /a that one should proceed forthwith to innovate in the various ways mentioned above. It would, however, be very useful to examine in more depth what is actually achieved in 3 years of upper primary science (for those who then drop out) and the further three years of secondary science (for those who continue). How much "scientific temper" is transmitted by non-experimental, rote learning?

(ii) How much significance should be attached to examination scores in science and maths as indications of learning? The rote learning system, with its precise notes, exam guides from the bazaar, supplemented by very large amounts

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(1) Evolving Systems op cit. p.13

(2) Ibid. p.8

(3) For a listing of some of these, see Proceedings of the Conference on Science Education op. cit

of homework (and occasional private tuitions) does presumably have some positive aspects. Is a poor teacher better with the old methods or the new? Is is possible to argue that the old system is more "teacher-proof" than the new? Given the importance attached to homework and frequent tests in many other studies of student achievement, there are perhaps some aspects of the existing science teaching that need closer analysis. It is worth noting that one of the researchers in Kishore Bharati has made a related point about the eventual examination results of the HSTP schools:

> After the middle school stage these students are not required to employ the qualities and skills which they are supposed to have acquired through the discovery method. Hence it would be expected that, in a traditional examination system, the performance of the students from the schools under the programme would be indistinguishable from that of students from schools where science is taught by the traditional method. An evaluation made recently confirms this hypothesis (1).

(iii) The larger question raised by these radically different teaching styles concerns their enduring effects. Examination scores are relatively meaningless when it comes to measures of creativity and independent thinking. It would be entirely possible for students taught in a discovery mode to do less well in formal examinations than ordinary students (the exams after all are a very close reflection of the teaching methods of the schools). The question then becomes what difference creative teaching makes in situations other than the examination? e.g. in technical work, in research activity, or in agriculture. Is there any link to the alleged lack of creativity of highly trained scientific manpower? What are the larger term consequences of exposure to the Homi Bhabha centre's supplementation, or to Hoshangabad? Is it worth conducting some analysis of the post-school consequences of really good science education? Although good education is intrinsically valuable, it may be worth looking in addition at the range of expectations that are assumed to flow from it. Sorting out the variety of these more or less idealistic expectations is itself important, for there is always a danger, as H.N. Sethna has warned, of believing "that science can achieve anything and solve any problem"(1).

(iv) A closely related issue concerns the quality of university-level trained science students. India has an enormous production of these, going to polytechnics, science colleges,

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(1) Rex D. Rozario and A.P. Gupte, "Science Teaching Programme in Hoshangabad District", Proceedings of the Conference on Science Education, op cit. p. 207

(1) Khiroda Conference Proceedings op. cit. p.21

engineering and medical schools. Teaching styles may not be that different in college than what has been described for schools, but again very little seems to be known with any certainty about the skills and attitudes with which people emerge from science colleges. Sethna of the Atomic Energy Commission has asked "what must be the quality of those third class (science) graduates, if we are finding the vast majority of even the first classes so pitiably ignorant in their subjects"(2).

(v) Science kits have been picked out in this paper because they are an indicator of a whole range of responses to what is seen as over-academic science teaching. But broader issues about the nature of educational aid and innovation strategies are raised by this subject. Kits are not necessarily synonomous with creativity and experimentation; they can open up inquiry or close it off. Again, kits can symbolise a more democratised access to experimentation (Parameswaran) or they can be as inert as any article too precise to use. So analysis of their utilisation in in order, to supplement an understanding of the ways science is learnt.

2. Science to the Community: Non Formal Science Education

Although it is a mistake too rigidly to separate non-formal science education from the issues discussed in the last section relating to formal sector science, the context and problems are sufficiently different that it is organizationally easier to draw some distinction between the two. However a number of agencies (including CSC Ahmedabad and Kishore Bharati) operate in both sectors, and are aware of the necessary connection between the two spheres of action. Given the drop out rate of 70% in primary education, and the very small proportion continuing beyond St. 8, Kishore Bharati have noted the contradiction between the objective of hoping to influence a majority of the age group and working in the school system. "Exploring innovations, methodologies and structures for such a large deprived community cannot be ignored. It has been our experience that such non-formal work not only has the potential of benefitting drop outs but also contributes to the enrichment of an environment-based school curriculum and teaching methodology".

The major conceptual distinction between formal and non-formal sector work is that the former, to have any influence at all, has to pay attention to school definitions of science. However creative, formal science education needs to relate at some point to the determined syllabuses. The starting point has to

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(2) Op. cit. p. 21

(1) Evolving Systems op. cit. p.15

be the existing definitions of science knowledge even if the intention is to expand these, subvert them, supplement or redefine them. In carrying science to the community, on the other hand, the enemy is much less apparent, and, accordingly, approaches are much more divergent.

One of the difficulties about analysing non-formal "science" education is that almost every type of rural development activity can loosely be seen as the application of scientific knowledge to rural areas. Village level health, agricultural extension, nutrition, contraceptive programmes, water development and energy experiments, all seem candidates for inclusion. To reduce the universe somewhat, it may be appropriate to look particularly at those initiatives which have had (a) a pronounced scientific research base at the heart of their activities, (b) have been investigating new ways of transferring science knowledge and new technologies to rural communities. It will be noted that the mechanisms for transfer frequently involve a participatory dialogue between the scientists and the village communities. This means, in turn, that several of these initiatives partake to some extent of the wider culture of popular participation and consciousness raising that informs so much of the voluntary agency world, either in theory or in practice.

(a) Elite Science and Rural Development

A feature of many of the most science-based endeavours is that they emanate from institutions of elite science, such as the Indian Institutes of Technology and the Indian Institutes of Management (IIM). These institutes, as we have mentioned, take students who have successfully survived one of the toughest examination marathons in the world, and are only too sensitive to sniping about their isolation and their failure to address themselves to research relevant to rural India. It is perhaps not surprising that small groups of faculty have over the last decade applied their scientific training to rural development and problems of ordinary education.

The example of the Homi Bhabha Centre for Science Education has already been referred to in relation to the Tata Institute for Fundamental Research in Bombay. That initiative was primarily concerned with formal schools, but other TIFR faculty have attached themselves to rural projects. In the case of IIM Ahmedabad, there has for seven years been a rural development project in Jawaja, a block located in the state of Rajasthan. IIT Madras has run a Centre for Rural Development since 1976, and the Indian Institute of Science in Bangalore has since 1974 had a cell for the Application of Science and Technology to Rural Areas (ASTRA). Finally, the Space Applications Centre (SAC), a part of the Indian Space Research Organization, has long had an interest in the social impact of both scientific and other programmes sent to a particular project area.

The Jawaja Project, Rajasthan

The aim of this project was to raise the technological and productive base of certain villages using a technology and pedagogy appropriate to the area, and engineering the changes in ways that increased local autonomy. We have seen earlier that making a small dent on the formal school system can require a major and sustained application of pressure from the change agent. This seems to be even more the case with even small scale non-formal intervention in the rural areas. One of the most remarkable aspects of the Jawaja project has been the detailed documentation by letters from the project team to one of the key officials in the Jawaja area. These letters lay bare the extraordinary range of contacts that the project leader, Ravi Matthai, brought to bear in the process of investigating new technologies, new sources of finance, and new markets for the produce of the weavers, spinners, leather workers and tomato growers. Agencies at the block, district, state and natural level were called upon for technical advice, support, markets[1]. Of the multitude of authorities asked for technical advice in the early stages of the project, there are mentioned: Central Sheep and Wool Research Institute, Central Glass and Ceramics Research Institute, Forest Research Institute, Central Cottage Industries Council, National Dairy Development Board, National Institute of Design, Weavers Service Centre, Council for Scientific and Industrial Research, Rajasthan Small Industries Corporation. Many of these were brought into a continous relation with the project, as was the Bank of Baroda for loans. Constant pressure and information exchange with the local administrative structures was also an essential component.

The list of high level bodies is not intended to suggest that this was an exercise in rural development by one powerful institution (IIMA) pulling strings, for there was an incalculably important input from the unpaid Independent Volunteers, and very genuine attempts to relate the technical advice to very specific village suggestions for new products. Rather, the importance of "The Jawaja Letters" (and the longer narrative account of the project) is attributable to the honesty of analysis of this intervention project. For anyone thinking that improving the design of the weavers and leather workers, and arranging small bank loans is something that can be rapidly initiated, and allow the project team to move on elsewhere, these letters are compulsory reading. There turn out to be almost endless ripples of obligation and accountability that spread out from the few initial changes in design, and in tanning technology; there is also a constant awareness of the trade-offs between fixing things and increased dependency.

There is always a tendency in looking at a project of this sort to ask what is generalisable, what is replicable. Given the hope that the scheme could illustrate an alternative learning system (hence the use of the term "Rural University"), it is appropriate to try and distill the essence of these 6 years of negotiated technological change. In such a skill-rich environment, is the new technology the least of the problems? Are the real learning problems the ones associated with sales, marketing, and the management of rivalry and competition? Beyond the historical detail of these "Rural University" letters, it would certainly be valuable to have a terse commentary on the lessons of

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(1) R. Gupta, Ravi Matthai et al (eds) "The Rural University": the Jawaja Letters /1975-79. Ind Inst Mgmt Ahmedabad Aug 81

negotiating the entrance of new technology. They certainly seem to be as complex and political as any major technology transfer at the international level.

Centre for Rural Development, IIT, Madras

At the other end of the scale from open-ended negotiation with existing village skills is the CRD, run by the IIT just at the boundary of Madras city. In contrast to Jawaja's decentralised groups, CRD is the expression on a single site of the concept of interlinking a series of available technologies and producing a commercially viable model of a miniature industrial estate. Unlike many government schemes which don't have to show a profit, the CRD was organized around a straight-forward bank loan of ½ million dollars, and the expectation that 300 new jobs could be found for the nearby villagers. The emphasis is on wage employment rather than self employment, and on modern technology rather than improved village technologies.

While Jawaja's technological changes have been principally related to one or two new woven products from new looms, and new tanning technology for new product markets, CRD, freed from the need to negotiate and improve on village technology, had within two years produced an entire integrated system: new construction technologies, biogas, energy, paper making, fish farming, rice milling, dairy, agriculture, forestry, water development, electronics, screen printing and plastics, soap making, garments, printing press, engineering products and carpentry.

Taken one by one, each of these activities is very common in any large town in India (with the possible exception of fish farming). The IIT's contribution has been their combination into a model micro-industrial estate. Like the IIM and Jawaja, the IIT can offer access to some protected markets and materials (scrap paper, printing orders, etc). It has also been able to rely on IIT graduates for its chief techno-economic officers in charge of the three main divisions of civil, mechanical and agricultural engineering.

It presents therefore a polar opposite to the Jawaja style. Both are concerned with new technology, higher productivity, job creation, and eventual local control of the new processes. The CRD has probably attached a larger number of villagers (300) than the total number of weavers, spinners and leather workers related to Jawaja. The general differences in style, however, are so great that it would be instructive to have a comparative critique of their impact on those they have sought to serve.

Space Applications Centre, ISRO

During the year of the Satellite Instructional Television Experiment (SITE) 1975/6, TV programmes were beamed to schools as well as broader messages to adults on agriculture, nutrition, family planning and animal husbandry. In fact the bulk of adult audience had a much larger proportion of basic entertainment, in addition to the subjects mentioned above. It was found in the school broadcasts that merely altering the medium of science education did not make much difference to understanding or school achievement. A TV science programme, like a science kit, does not have a life of its own, but is highly dependent upon intelligent pre and post telecast discussion by teachers. On the whole these pre and post-sessions did not take place, despite teachers being given TV orientation to utilising the programme to the full.

As far as broadcasting to adult viewers is concerned, SITE provided an important learning experience for SAC. It had become clear that the software was much more difficult to plan than the hardware. Beaming science-based information in agriculture, nutrition or health told one very little about the nature of the programmes' impact. Nor did a once-only summative evaluation indicate the complexity of the development communication process. Indeed a major research outcome of the SITE year was the recognition that both quantitative and qualitative methods of evaluation would need to be followed, accompanied by an indepth anthropological study of the process at the village level if social science was to profit from this novel communication.

In the years that have followed the end of the first satellite transmission, SAC has continued to beam its own TV programmes to part of Kheda district in Gujerat, but there has been a significant shift toward/ decentralised and participatory /a communication process. As an analogue to the more participatory attempts to teach science discussed above, SAC began to explore with villager cooperation some of the major social and economic problems of rural life, especially for the lower castes. Direct villager involvement with social scientists and communication scientists in the production of TV programmes raised awareness of problems with an immediacy not easily found in other media. For example, filming a politician preaching against caste, asking for water and refusing to accept it from a harijan, then filming villagers discussing the rights and wrongs of the situation turns out to be a very potent message if beamed back to the very villages experiencing this. So potent in fact that there are real dangers and moral dilemmas posed in broadcasting these films.

The SAC example may seem somewhat remote from the other illustrations of taking science to the people; it is different principally in having moved from a centralised transfer of science-based information to a decentralised participatory process. In the interim, faith in the power of science information by itself to make an impact has been altered towards a social science appreciation of the conditions of impact. As Insat is in position from mid August '82, SAC's experience in transmitting both science and social science to villages will be vitally important. What they have learnt from both formal and non-formal science programming should be available for this next round. But to what extent have the SITE lessons been more wide absorbed, especially SAC's view that "the planning for software aspects of communication technologies must start

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many years prior/the planning of hardware aspects" (1)? /to

Application of Science and Technology to Rural Areas (ASTRA), Indian Institute of Science, Bangalore

The last of the initiatives emanating from the most prestigious science and technology management institutions is ASTRA(2). It was not possible to visit ASTRA's staff or its extension centre in the rural areas. But there exist several accounts of the Centre's work, which allow one to see that ASTRA is much the most "technological" of those we have treated so far. Its role is primarily to work on the generation of new technologies for villages, and to try these out in the extension centre, as far as possible in active collaboration with villagers. Dr. Amulya Reddy, the ASTRA director, is aware of all the dangers of scientists generating appropriate technologies in complete isolation from village reactions and rural conditions. He is also conscious that the status of scientific work for villages will tend to be downgraded in a high powered science institution; hence he has had to argue that simple products and processes require sophisticated thinking and research. Indeed "efforts to generate appropriate rural technologies necessarily require more, not less, simultaneous emphasis on basic research and fundamental science", (3) since there is no beaten track from which to start.

There are intriguing differences between the ASTRA approach and that of CRD in Madras. The latter spent much less effort on the generation of intermediate technologies, but innovated in the inter-linking of a series of broadly modern technologies. ASTRA has felt it important to try and "expose the people to a wider range of technological options instead of the two-option Hobson's choice with which they are currently confronted - either suboptimal traditional technologies or far-too-expensive "modern" technologies(1). There are major differences also in the extent of negotiation and popular participation. Obviously CRD's operation that needed rapidly to become commercially viable acted under greater constraints than that of ASTRA.

ASTRA has sought to reflect on what they have learnt from the model they have applied since1974(2). In particular

(1) E.V. Chitnis quoted in Binod Agrawal, SITE Social Evaluation Results, Experiences and Implications, Space Applications Centre, Ahmedabad, 1981, p.60

(2) Beyond those mentioned, there are rural activities in other IITs and IIMs.

(3) A.K.N. Reddy, ASTRA, in K.P. Kannan (Edit) Towards a People's Science Movement (KSSP, Kerala, 1979) p.22

they have analysed the structural connections between the science training system with its set of values mirrored from developed countries and the need to generate and diffuse new technologies for rural areas. They see the patterns of technological capability distorted towards the problems pre-occupying the developed countries. This in turn is reinforced by the foreign graduate training of the best science students.

> No wonder that most foreign returned scientists and engineers spend the bulk of their remaining active professional lives continuing the themes of their foreign researches even though the stark reality outside their laboratories and workshop is clamouring for a local commitment and a native orientation.(3)

In this situation, it would seem that indigenous technological capability is neither being developed adequately to modify or challenge western industrial technology, nor to develop a wide range of newer small scale rural technologies. With the orientation of existing scientific research firmly fixed on the urban industrial sector, one wonders what progress has been made in institutionalising the rural commitment of scientists. Reddy correctly looks to re-orientation of the existing educational infrastructure rather than the creation of a few institutes for rural technology; but one wonders what progress has been made over the last decade in research re-orientation towards rural requirements Has the pattern of annual scientific awards at all altered to recognise the kind of work ASTRA has been promoting? Have the various cells and individuals dedicated to these rural technologies become regular departments or faculties of universities? Is this thrust becoming part of the regular academic programme, and "not an extra-curricular activity of a few scientists/engineers with an urge for social work"?(1) Some indications of what might be expected in such a re-orientation have been sketched out by Prof. B.M. Udgaonkar of TIFR(2), but there still seems to be a tendency for the rural technology cells (or other initiatives) to be quite on the periphery of the prestigious institutions which house them. It would be useful to analyse to what extent there have been significant changes in research emphasis, and what are the limitations that may be expected in any such redirection of science towards community service. Even if most major institutions now have some sort of window on rural development, what kind of influence have these had on the regular departments and student

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(1) Reddy op. cit. p.16

(2) Reddy op. cit. pp.20-23, and Reddy et al, "Problems in the Generation and Diffusion of Appropriate Technologies - an Institutional Experiment", in S. Radhakrishna (ed), Science and Technology for Integrated Rural Development (COSTED, Madras, 1977) pp.147-164

(3) Reddy et al op. cit. p.137

participation? To use Kishore Bharati's term, what sort of "dent" has been made in mainstream science by the presence of the rural scientific extension centres. Any analysis of progress and achievements these last ten years would have to pay attention not only to the few institutions mentioned here, but also to assessing the Karimnagar experiment in Andhra Pradesh, which was the rural experiment and demonstration centre of the Council for Scientific and Industrial Research (CSIR)(1), and several other initiatives.

In this section on the rural aspect of certain prestigious science institutions, it would also be worth noting the role of the Committee on Science and Technology in Developing Countries (COSTED). With its secretariat in India, at Madras IIT, and its president the vice chancellor of Nehru University, it has had a particularly close liaison with some institutions mentioned above. Indeed, its scientific secretary, S. Radhakrishna, is also the chairman of the Centre for Rural Development at IIT Madras(2).

In many of these various exercises of what we have termed elite science institutions, there is a need to take stock, and look across institutions at what has been learnt in common about different methodologies, communication strategies, ways of negotiating on technologies with villagers.

(b) NGO Science for Communities

Beyond the several attempts by renowned institutions to relate to rural communities or rural technologies, there is a wide scatter of non-government agencies committed to similar sounding goals. Some of these are national, some statewide, some very localised. Although some are linked to political parties, many are explicitly delinked and yet are working on the major issues of social transformation with particular communities. For many, the potential of science is strongly affirmed, but they are disenchanted with the official recipes and structures for "delivering"

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(1) Reddy "ASTRA" op. cit p.14

(2) B.M. Udgaonkar, "Science and Technology for Rural Development: Role of Institutions of Higher Learning" in Reddy et al op.cit pp.74-105

(1) For more detail on CSIR's Karimnagar project, see Hari Narain, "Karimnagar-CSIR's Experiment in Integrated Rural Development", in Radhakrishna (Edit) op. cit. pp.106-120

(2) Its president, Y. Nayudamma is now a governor of IDRC

science. D.L. Sheth, who has been studying the new politics of these NGOs has commented:

> --the educational and professional establishment are fast losing their credibility as instruments of modernization. The magic of the "science of management" is fading away. What once looked like problems solvable by proper application of social science knowledge and modern management now appears to lie beyond their ken -----
>
> All the programmes and activities of the established institutions now look lustreless; they hold no promise of solving any real problems of the poor. Now the university graduates going out to work with the people acutely feel the need to delearn what they have learnt in these institutions(1).

As it was not possible to spend time with any of these groups, reliance must be placed on written sources. This is seldom satisfactory, since many of the groups do not have the time or inclination to commit much to paper. Hence there is a natural tendency to overemphasise the significance of the more formal institutions which have the infrastructure to produce annual reports, evaluations and conference papers. By contrast, the process of documenting science to the people via NGOs is much less straightforward.

Two exceptions to this relative dearth of written material are Kishore Bharati and KSSP (the Kerala Science Movement). Both of these, we noted, had a concern with formal science in schools, but have also made major contributions to understanding the role of science in relation to rural communities. Useful recent documentation on what they have learnt in the process of carrying science to communities is available in two key statements:

1. Science for Social Revolution (Kerala Sastra Sahitya Parishat, 1980) and
2. Anil Sadgopal, "The Place of Science in a People's Movement", Vikram Sarabhai Memorial Lecture, August 1981, reprinted in ICSSR Newsletter, XII(1), April-Sept. 1981

These documents are valuable summaries of work during the 1970s in Kerala and Madhya Pradesh, but for our present purposes they also serve to differentiate science-based

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(1) D.L. Sheth, "Movements and the Future of Politics" VII World Conference on Future Studies, June 6-8, 1982 (World Futures Studies Federation) mimeo, p.22

rural development from many other varieties of action programme in rural areas. In examining Kishore Bharati's attempts to apply science and technology, Anil Sadgopal draws a distinction between observation of reality in the social science and in the natural sciences. Although observation, data collection and inference are common to both, experience with Kishore Bharati had shown how frequently in social science the aspect of reality perceived was related to one's cultural and economic background. Observation of the "needs" of rural people differed widely depending on the nature of analyst, whether aid agency, government department, rich farmer or poor. "In contrast, the process of observing and analysing reality in the natural sciences is dependent only on the scientific skills of the worker, and not on his or her class background"[1].

This ability to observe and conduct analysis in the natural sciences is not something that is the prerogative of the educated; the poor can be trained to it. Indeed the method of science can be spread amongst the poor so that they can perceive their own socio-political reality, and can plan their own development "on the basis of reliable data and logical thinking".[1] However, the problem in popularising scientific method, or scientific temper seems to be two-fold. As far as those currently applying science to rural areas is concerned, the objectivity mentioned above soon vanishes:

> the moment one begins to relate science to the problems of society (for example, the case of technology) the class affiliations and the vested interests of the worker begin to influence his or her objectivity in a manner similar -- to the social sciences [2].

Sadgopal has no shortage of illustrations of how the process of applying technology -- whether wells, improved cattle, improved potting, science aids -- has reinforced inequality; the scientific temper is quickly overlaid by the class interests of those mediating and distributing the technology. On the other hand, the scientific method is still very inadequately understood by the poor, and where it exists potentially, it is constantly being undermined by lack of information, fatalism, fear of reprisals, and inability to generalise and abstract. These continually interfere with accepting the logic of scientific analysis, just as other forces distort the application of science and technology through the official channels and agencies. There is thus a kind of dialectic that needs to operate

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(1) Sadgopal, op. cit. p.14

(2) Ibid p.14

continually between political or other impact upon the barriers to self-perception and the process of education in scientific methods. The dynamic relationship between scientific method and incremental political changes is at the heart of Kishore Bharati's experience:

> The educational work of spreading the scientific method does not progress as long as such barriers continue to exist but can be started all over again once these barriers have been broken by mechanisms which are beyond the realm of science[1].

The "syllabus" of non-formal education (science for rural communities) is thus a good deal more complex than the inquiry-based science teaching programme in schools. The former proceeds by fits and starts. If "inquiry" is the active ingredient in the school science scheme, political action or insight even on a micro scale, can be its equivalent in the non-formal, community science. For example, seeing a common village scene of discrimination against harijans heightened by a SAC telecast. The parallelism between the formal and non-formal sides of Kishore Bharati has been touched on earlier, but put another way, it could be said that science via the inquiry method produces a challenge to traditional methods, and hopefully produces a more creative worker, while amongst the peasantry the hope is that scientific methods can become part of a people's way of thinking, and can in turn challenge the vested interests in the village and countryside.

The latter may sound rather idealistic, but certainly it would be interesting to have documentation on how this non-formal science "syllabus" has worked out in practice with some of the communities in the vicinity. Presumably one of the moral dilemmas central to this pedagogy is how to handle the awareness raising aspect, without which the cognitive work on new science-based knowledge and method may sometimes lie inert.

It is not possible here to go into the methodologies of the many other science movements such as the Centre of Science for Villages in Wardha, the Society of Young Scientists, the initiatives of Dr. Shankar Chakravarty in West Bengal, the Science Education Centre in Attara, Uttar Pradesh. Nor will we go further into the relatively well documented KSSP in Kerala, beyond stressing that its action research component has become increasingly important in mobilising local and state wide opinion against the misapplication of technology in development schemes[1]. What would be useful, however, would be to have a review of the different "characteristics of "science" within these,

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(1) Sadgopal op cit. p.19

(1) KSSP, Science for Social Revolution (Trivandrum, 1980) 26 pages, and Towards a People's Science Movement (1979)(Trivandrum) 206 pages

and the range of ways that scientific knowledge and method is related to popular participation and community transformation.

3. Acquisition and Utilization of Science and Technology in Industry: Formal and Non-Formal Patterns

Our concentration thus far has been very much on problems connected with the learning of science in schools, and colleges, as well as non-formally in villages. There is no doubt that there is concern also about the acquisition and utilisation of science and technology in industry, even though we have noted a widespread feeling that the science system is already too much oriented to industry.

One set of issues seems to relate to the disjunctions between scientific research and industrial adoption. Despite research being pre-occupied with industry and commerce (rather than rural development), it still seems to appear irrelevant. Allegedly the research and the prototypes produced in many of the national institutions are remote from possible applications. It is not infrequently that the National Institute of this or the National Laboratory of that is being chastised for having virtually none of its products or prototypes adopted. Various reasons for the malaise are often suggested in the intellectual weeklies, in readers' letters, and in conversations. They tend to mention the bureaucratic structures of the institutions, the lack of personal and structural incentives to creativity, a lack of commitment to productivity, authoritarianism by institutional heads, and the derivative nature of the research done in Indian labs. The following perception is widely shared:

> The practice of science in India is imitative and not innovative. Our scientists add to the data that no more than confirm the conclusions reached elsewhere. The local needs and resources are seldom the subject of Indian research. This is why we neither have Indian science nor Indian technology. Originality and inventiveness are derived and if pursued, in spite of derision, punished. The science administration is by and large unscientific (The Hindu, July 8)

On the other hand, the official view of the Council of Scientific and Industrial Research (CSIR) with its 35 national laboratories, 71 extension centres& regional labs, is that it renders wide ranging services to support the national infrastructure in the achievement of self reliance. It sees itself as one of the largest state-supported R & D organizations in the world. No less than 4,500 scientists are on roll, supported by 14,000 staff. The total number of processes released to industry up to 1981 was 1,293 of which 571 are reportedly in production(1).

(1) A.M. Zutshi 'Gulzar', PRO,"CSIR and National Development", Mainstream. XIX, No. 51. August 1981. pp.30-34

However that may be, there seem to emerge constant reports about the conditions under which scientists have to work, their subjugation by the bureaucracy, the failure of their professional associations to support them or criticise them when appropriate[2], and, of course, running through it all, the alleged irrelevance of their research endeavours.

In this atmosphere, it is not surprising that some scholars should have tried to examine this research culture more closely, and ask questions about the truth of the caricature. One of these, Dinesh Mohan, has even tried to get some sense of where Indian science stands internationally, by looking at their standing against a series of rough and ready benchmarks of quality (International and national awards, appearance in most cited articles, faculty members of highly rated universities etc. etc)[3]. The outcome is very tentative but both at home and abroad it seems that Indian scientists are not making their presence felt in the innovative or frontier areas of research and development.

For our present purposes, what is of interest is whether there is any particular reason to believe that the educational system itself has any part to play in the production of this research malaise. We have already noted the extraordinary concentration on reproducing exactly the knowledge given by text book and teacher, at every level of education, and we have also paid some attention to the agencies trying to instill discovery and creativity into primary and middle school. Doubtless, part of their rationale for promoting discovery science in school is their awareness of bureaucratised research at the post-college stage. Mohan himself, teaching in an IIT, is clear that early education is quite largely responsible. Some of this is attributable to the perpetuation of a colonial education discouraging Indian innovation, some to the uncritical teaching and learning style of present institutions, and some (perhaps a great deal) due to the continuation of English language, dividing India still into two nations:

> The persistence of English as the language of Indian science and technology automatically precludes the participation of the overwhelming majority of India's population in the scientific culture. Most of those who still manage to engage in scientific activity do so at arm's length and at an enormous cost. They are forced to conceptualize and be creative in an alien medium[1].

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(2) K. Ashok Rao, "Role of Professional Societies in the Development of S and T in India" IIT, mimeo 1981

(3) Dinesh Mohan, "Sea of Mediocrity", Seminar, Feb. 1981

(1) Mohan, Ibid

Obviously, there are no single factor explanations of these features of the research culture. In the academic institutions and government research laboratories the role of funding is critical in addition to all the other factors mentioned. While in industry itself, the extent to which research is at a premium will closely relate to whether the company is reproducing technology through collaboration, or developing new products on its own. There may, however, be some merit in suggesting that the specifically <u>educational</u> contribution to this problem be examined in a little more depth.

It is possible that this issue has already been over-examined, but there may be room for some of the following:

- A review of studies that have analysed the higher educational environment in which the research culture is nurtured.
- Qualitative studies of university science environments, and of particular research labs.
- Analysis of what studies have been done on the role of research in the private sector.

This last is particularly crucial for a better understanding of research potential and its utilisation in industry. One relatively common view is that there too, like the government sector, there is hardly any science-based innovation. It is argued that industrialists want a foreign collaboration for even the simplest product[1]. More specifically it has been said of the pharmaceutical sector that despite claims of significant inhouse R & D in India, not a single drug has been discovered by any of the main centres:

> A large part of the so called research is actually quality control, market studies, clinical trials and other similar activities ---- None of the projects carried out address themselves to the basic problems of major illnesses like tuberculosis, leprosy, malaria, diptheria, gastro-enteritis, etc.
>
> Since R & D expenses in India are relatively low, the facilities of some of these laboratories are utilised to carry out basic research required by their parent companies who themselves carry out the intermediate and penultimate stages, keeping the Indian subsidiary in the dark[1].

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(1) Mohan, op. cit

(1) M.S. Iyengar, "The Status of Research and Development in the Private Sector", mimeo, Dept. of Mechanical Engineering, IIT, Delhi, p.9

The terms in which these discussions are carried on may seem somewhat overdrawn, but they indicate a little of the sensitivities and concerns about creativity, innovation and nationalism that emerge whenever the role of research in industry is discussed. They are part also of a wider debate relating to indigenous technological capability (ITC) and this in turn has sought to examine the historical differences between Indian and other Asian industrial nations (notably Japan) in respect of research and innovation[2].

Scientific research and industrial innovation, however, is only one aspect of the many possible relationships between science, technology and education in industry. Doubtless, case studies of particular firms would be valuable, especially if attention is paid to the varieties of ways in which innovation can express itself apart from major technical advances. But there are many other facets of ST and E that seem equally important.

The changing pattern of utilisation of technologically trained manpower is an area that seems crucial, and this in turn has a very close and and dynamic relationship with the planning of different categories of higher technological education. There has, for example, until recently been a tradition of limiting rather strictly the expansion of engineering colleges, and above them the Indian Institutes of Technology. This has then offered a certain premium and protection to the engineer over other forms of technical and technologically trained manpower. One consequence of this special treatment for engineering colleges has been that much more attention has been paid to evidence of unemployed engineering graduates than to other categories of science graduate. Indeed, it could be said that very much less interest attaches to the notion of unemployed science graduates than to engineers.

These processes of limiting seats for certain vocations and being relatively flexible with the expansion of science colleges produces a hierarchy of preferences within the education and training system. This sets up very powerful pressures to expand those sectors most protected by limitation of seats. Hence, in difference States the emergence of private engineering colleges, particularly in Karnataka, Andhra Pradesh and Bihar[1].

As the tussle goes on between limitation and expansion in the few protected islands of India's sea of higher education, it is important to look at a double set of influences: the backwash on schools and the "forewash" towards industry. Science continues to be critical in schools as only the highest

(2) see papers by Ashok Desai, Ron Dore and Tom Eisemon, at Conference on ITC, Centre of African Studies, Edinburgh University

(1) The Hindu July 18, 1982

possible exam marks will secure a place in medical or engineering college. Once that selection has taken place, however, pure science becomes much less important; indeed entry to polytechnics is more favoured than the ordinary range of science colleges. The status differences then amongst the three groups (engineering degree holders, engineering diploma holders, and science graduates) are much wider than would be anticipated, and have important consequences for the pursuit of science knowledge in the different institutions.

On the industrial side, the utilisation of these and other categories of trained manpower is presumably a good deal more untidy. Employers are aware that the brightest students in the school system have entered engineering colleges (including IITs which are basically engineering colleges). They may then be tempted to recruit them as managers as much as for their engineering skills. This position of engineering as the flagship of the science training system probably produces some distinctive patterns of industrial organization. First, there are likely to be a larger group of top managers with engineering backgrounds than in many other countries. No bad thing, it would be thought, compared with systems where management has a non-technical background. However, the very status and aspirations of the engineer, at the peak of the education system, may lead to his under-utilisation in the sectors for which he was prepared. This tendancy could well be compounded by the existence of the large informally trained labour power:

> in many industries, both large and medium scale, there has not been full utilisation of the products of the engineering education and training system. Partly on account of economic reasons, and partly because of a failure to upgrade technology, the engineering graduates and diploma holders have not been fully utilised. Many industries continue to use a large number of unqualified technicians and even engineering supervisors. The private sector particularly finds that experienced workers, mainly those who enter the factories at lower levels, are better at handling production than fresh diploma and degree holders; and therefore it continues to use a large number of "praticals"(1)

It would be dangerous to generalise before looking in much more detail at the utilisation of different grades of manpower in different kinds of firms. For example, one firm that was visited had no less 60 engineering graduates, 60 engineering diploma holders, and a small number of science graduates. A

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(1) Mahesh Verma, "Planning for Development, Training and Utilisation of Manpower in Industry and Agriculture", Planning Commission, New Delhi, mimeo p.10

third of the whole workforce was derived from these three groups. Significantly, this enterprise was making a moped without any foreign collaboration. Doubtless, very different mixes appear in other kinds of firms, and these will be different again from the more standardised ratios of engineers to other categories in the railways and public sector concerns.

Overall, however, the widespread availability of both formally and informally trained manpower has meant that firms could increasingly draw upon more educated, science-trained candidates if they so desired. To the extent that firms do use these, it would be interesting to know what difference to quality or productivity it really makes to employ a virtually graduate and school-leaver workforce. It is often assumed that an oversupply of ordinary science and arts graduates is wasted if they work in firms that don't really require their level of knowledge and expertise. But very little work has been done on the phenomenon of "over-education".

It is possible that the real merit of having an over-supply of various categories of scientifically educated worker is their capacity to master rapidly the techniques of production, and in due course set up on their own. One's impression is that this moving into self-employment happens very widely. Many factors fuel this, but the ease with whcih an entrepreneur can find the talent available is clearly an important one. Among questions that could be addressed in this situation would be:

- Amongst communities (e.g. Gujeratis and Sindis) that have a long tradition of business enterprise, does it really matter that their formal education is such as has been described earlier? Does examination-oriented, non-discovery schooling really make for lack of initiative and creativity? Home influences perhaps continue to be more powerful than the school and encourage creativity and enterprise that the school has not wiped out.

- Amongst groups where there is little home stimulation towards independent thinking, and new work experiences, then the school has an enormous gap to close. It will take all the power of Hoshangabad science to compensate for the home environment.

- Learning on the job vs learning institutionally. Presumably there is a changing relationship between these two learning arrangements as the workforce, including craft level, becomes more educated. In the newer knowledge-based industries, the trend towards institutional learning will be most marked. But even in the older industries like foundries where workers' formal education was minimal if it existed at all, it would be interesting to examine the impact of secondary education upon greater concern with quality, etc.

- Analysis of the unqualified technician or "Mistry": An important aspect of learning on the job relates to the hundreds of thousands of "mistries" (senior mechanic or master) who in countless workshops across the country are responsible

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for welding, painting, building, machining, automotive repair, etc. etc. Are they a case of the good being the enemy of the best? In the sense that their learning has been rote, trial and error learning, and that they have little or no theoretical knowledge, they have been characterised as highly individualistic, yet conservative. They extemporise, but do so in a setting of un-standardised machines and products. At some point they too seem to relate to the problem of quality to which we have kept returning --"the technical outcome of this fantastic expertise is often uncertain. Poor quality of craftmanship and low maintenance standard of service equipment - from bicycles, automobiles, electrical goods, to manually-operated mechanical systems of all kinds bear testimony to this -- unfortunate state of affairs"(1).

4. Changing Ideologies Towards Science and Technology

In general, the various centres and groups mentioned in this paper have regarded science and technology rather positively. Certainly science would have to be taught better to have an impact and technology be more oriented to rural problems, but the extension of scientific method was not itself under dispute. In parallel, however, with the growth of groups concerned with the extension of scientific temper to poor schools and backward classes, there has grown up a critique of the role of science and technology in Indian society.

Over against the calls for scientific temper, or for national science campaigns directed towards poverty, disease and ignorance, science studies groups have drawn attention to the need more dispassionately to disentangle the relationships between state power and the science establishment, between contract science research and uncommitted research in universities (2) and between the extension of modern science and the existence of local knowledge systems. One dramatic presentation of some of the issues in dispute between scientific temper and scientific danger exponents is available in the contrast between two short tracts. They offer a valuable counterpoint to the more applied research topics we have been discussing:

1. A Statement on Scientific Temper (Mainstream, July, 25, 1981)
2. A Counter-Statement on Humanistic Temper (Ashis Nandy, Mainstream, Oct. 10, 1981)

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(1) Aqueil Ahmad, "Scientific and Technical Human Resources in India". National Council of Science and Technology Panel on Futurology, DST, April 1977

(2) Dipunker Gupta, "State, Science and Universities", op.cit

These contraversies about the role of science are not necessarily academic. The signatories to the Statement on Scientific Temper work in major science teaching and research institutions, including some of those mentioned in this paper, and are concerned to challenge the obscurantism of many areas of Indian life. There is a near missionary note in parts of the Statement ("Our Nation's survial and its future depends on upholding Scientific Temper . Superstition shall not pass and darken its portals"(1)), but the group are sufficiently scientific to want "to combat the tendency to treat science and technology as a sort of magic". Problems of caste, class and corruption do not crumble away in the face of science, but "when the social structure and stratification prevent the application of rational and scientifically proven solutions, the role of Scientific Temper is to lay bare the anatomy of such social barriers"(1).

This laying bare is not intended as an empty aspiration, but has already become, as we have seen, the method followed by Kerala's KSSP in making villagers aware of the politics of pollution and other development problems(2). It was also part of Kishore Bharati's non-formal science education, and figured prominently in the series of "awareness" films produced by the Space Applications Centre. It would, however, be rash to suggest that science is yet being widely sued to demystify systems of oppression.

Indeed, the Counter-Statement would want to argue that science and technology have themselves been so intimately linked with oppression that they constitute a rather ambivalent armoury to wield in favour of the oppressed. The critics of "development science", notably the Centre for the Study of Developing Societies, have increasingly begun to carry the debate about science beyond the pages of the academic journals and weeklies, and into discussions with activist groups around the country. In particular through their involvement with Lokayan, the loose network of activist groups in different states, the Centre (CSDS), has been drawn into discussing ideologies of science with some of the very groups using science in social transformation (3). In this connection, it would perhaps be valuable to have CSDS examine in some detail the assumptions about science and technology of the myriad groups flying a science flag in their rural development and education endeavours.

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(1) Statement, p.9

(2) "When we visited this village last year, we were amazed to see how technical terms such as sulphur dioxide, carbon monoxide, percentages and solubility had become part of the common idiom". Sadgopal, op. cit.

(3) Lokayan, Bulletin No. 5 (Lokayan Delhi, Feb. 1982) pp3-11

Conclusion

What stands out in this brief paper on Science, Technology and Education in India is the particularity of the science research environment. India has acquired an enviable position in its application of science and technology since 1947, compared with many other countries. Products can be as rapidly put into production as anywhere in the world. The design may be originally derived from elsewhere but there is frequently considerable originality in reproducing it in India. Some corners are cut, some quality is let slip, some packaging and presentation cheapened. But a local version of virtually everything is available in India.

The comments made here are not intended to question this achievement of self-reliance, but rather to reflect some current concerns about the science training and science utilisation policies that are related to these achievements in agriculture and industry. The ferment about scientific research, the education of scientific manpower, and the role of science in rural transformation are all high on the agenda of the research community. It seems that the lessons and experiences of the 1970s are beginning to come into sharper focus, and plans are being laid in many centres, institutions and agencies for the more targeted application of science, technology and education to rural and industrial development.

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