SOME PRACTICAL SUGGESTIONS FOR THE IMPROVEMENT OF SCIENCE IN DEVELOPING COUNTRIES

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IN a previous article,[1] I discussed some of the reasons for my belief in the importance of a newly developing country creating a firm foundation not only in applied but also in basic research in the natural sciences. Following that general discussion, I would now like to turn to the listing of some specific and concrete steps that can be taken to achieve the general goal.

It might be well to begin my discussion of a controversial problem with a note of caution. My own personal experience with the problems described in this article has been gained mainly (although not exclusively) during the academic year 1962–63, which I spent in Pakistan as a temporary employee of the International Atomic Energy Agency, assigned to the Pakistani Atomic Energy Commission's Atomic Energy Centre in Lahore. It is possible that this experience does not allow an immediate generalisation to other developing countries with completely different historical, cultural and political backgrounds, such as Nigeria or Uruguay, and thus my conclusions might be valid mainly for the Indian subcontinent.

When a Western "expert" visits a university in a developing country, he often finds himself requested to review the local syllabus or curriculum and to suggest changes. He also often hears complaints about the absence of textbooks and other instructional aids. Indeed, there is much to be done to improve the situation in these respects. But he is also likely to come to the conclusion that the main trouble with science education at these universities lies in a different domain which is more difficult to convey to the local staff and even more difficult to remedy. The problem is not with *what* is being taught but with *how* it is taught. There is an overwhelming tendency on the part of the staff and the students to consider science as a collection of facts to be memorised, an abstract discipline consisting of general laws of nature, the faultless recitation of which makes a well-qualified scientist. That the best way to absorb science is to work out problems is very little appreciated and hardly ever practised. I have encountered undoubtedly very bright young men in Pakistan who represented the top of their class at the best Pakistani universities, and who

[1] "Technical Assistance and Fundamental Research in Underdeveloped Countries", *Minerva*, II, 2 (Winter, 1964), pp. 197–209.

could rattle off the second law of thermodynamics much better than I can, but who, when confronted with the question of what happens to an insulated room when a working refrigerator with an open door is placed in it, not only did not know the answer, but failed to realise that this " silly " question had anything to do with thermodynamics.

What can be done to foster the transition from learning by rote to the perception and selection of problems among those who have concluded an undergraduate course in physics and who would like to go on to post-graduate work abroad? The Atomic Energy Centre where I was stationed in Lahore has a training programme for its young employees (most of whom have received an M.Sc. degree at one of the Pakistani universities) prior to sending them abroad for further training. This programme now includes three courses, in mechanics, electrodynamics and modern physics, respectively, based on American textbooks I recommended; the books and the courses lay heavy emphasis on problem-solving. Courses like these might make the transition to the style of work of a Western graduate school less painful. Not less important would be the experience which local teachers would gain in teaching in a more problem-oriented manner.

Postgraduate Education

Although it is very desirable in the long run for an underdeveloped country to be able to train its scientists at home on the postgraduate level too, this is likely to come only at a relatively advanced stage. In the meantime, such training must be obtained at Western graduate schools. This raises many problems.

The very first one has to do with obtaining admission and financial support at a Western graduate school. The pressure for places has been increasing every year and the better schools sometimes have 10 times as many applicants as they are able to admit. In such a situation an applicant from an underdeveloped country has many handicaps from the very beginning. Quite often the record of his predecessors in that department is not too distinguished. Furthermore, his application is supported by academic records which tell very little and by glowing letters of recommendation from completely unknown teachers, who often consider it a feather in the cap of their own prestige if another student is admitted to a Western institution. Since such an applicant represents so many question marks, he is most likely to be turned down by the graduate school which cannot afford to take chances with its scarce places.

There are several possible remedies for this problem. An admittedly stop-gap measure is the one I have tried with trainees of the Pakistan Atomic Energy Commission. I have made arrangements with about a dozen good American graduate physics departments, under which I help

to assure them that the Pakistani students I recommend to them are in fact prepared for Western postgraduate physics education. In return the schools are willing to consider the applications of these students in the light of this additional information, although, of course, this does not mean automatic admission and financial support. My own recommendation, in turn, is arrived at in the following fashion. First, there are some Pakistani colleagues whose judgement I have come to rely on and who can compare for me the new applicants with previous applicants, some of whom might already be successfully engaged in postgraduate work in the United States. Second, I have prepared a written examination (consisting mainly of problems), based on the A.E.C. training programme I mentioned in connection with undergraduate education. This examination is then given by a colleague in Pakistan and is forwarded to me for review.

This method is admittedly awkward, piecemeal, and cannot be expected to work forever, as my personal contact with the Atomic Energy Centre becomes attenuated. One would think that some universal written examination could be worked out, similar to the Graduate Record Examination, which could serve as a fair indication of the candidate's ability and preparedness. Although several organisations are working on the construction of such examinations, I doubt very much that they will be successful. Because of the great discrepancy between the educational methods of the different parts of the world and because of the specific shortcomings I discussed above in connection with undergraduate education, I believe that such an examination would indicate very little.

My suggestion for a more permanent and more efficient solution of the problem of selecting students for postgraduate education in the West is the establishment of *ad hoc* interviewing committees which would visit the various universities and interview, for an hour or so, each candidate who wishes to apply to a Western graduate school. A committee of three physicists, travelling for one month, could probably take care of all applicants for physics postgraduate education in all the Asian countries, at a total cost of less than $15,000. It has been my experience that an hour-long interview offers an excellent opportunity to make a fairly reliable judgement of the applicant's accomplishments, capacities and weaknesses. This assessment, should he be admitted to a foreign graduate school, would be valuable information for his supervisor there. The information obtained by this committee would, of course, be made available to any university which might be interested in it.

During the past two years I have been trying to persuade a number of American foundations and government agencies to support this scheme and, while everybody seems to be eager to see it carried out, actual financial support has not yet materialised.

The next question that arises in connection with graduate education is related to the branch of science in which a student should be trained. In order to be able to offer the student, at the completion of his education, a position at home in the proper field, he must be trained in a field which is in fact being worked on at home. At the same time, practice has shown that a simple order prescribing the field of study for a student never works, and perhaps rightly so. The rather obvious solution of this problem is to place the student in a Western university where the field of science which his home university or laboratory has in mind dominates the department and where the student is likely of his own volition to choose that field. This arrangement should be followed even if a particular university is perhaps not as excellent in an overall sense as another in which the particular field is less strongly represented. Since the worship of "great names" among universities is even more pronounced in developing countries than in advanced ones, this procedure requires a certain amount of self-restraint. It is, however, indispensable because it is extremely difficult to change the field of interest of a student once he obtains a Ph.D. in that field.

The Effectiveness of Postgraduate Study

Now let us assume that the student has been able to find an appropriate university, obtained admission there and received financial support. What can be done at this stage to make his transition to his new environment easier and more effective?

First, it must be realised that in most cases such a student will need a lot of individual attention from his adviser and that this attention and cooperation must often be initiated by the adviser since the student is too shy or confused to do so. One of the most important functions of the adviser is to ensure that the student does not take too heavy a load of postgraduate lectures and seminars if his undergraduate background is not absolutely sound. More often than not, such a student will in fact need one or two terms to take some advanced undergraduate subjects to catch up with his Western contemporaries. He will consider the taking of such courses not only a personal affront (being used to being the much-admired top student of his class) but might even consider it a tragedy since it might delay the completion of his doctorate by a year. The emphasis on the formal aspects of education in the developing countries manifests itself not only through the formalistic attitude toward science teaching and learning but also in the excessive concern with degrees and titles. Even if the student's financial assistance is assured throughout his course of postgraduate study, he will want to obtain his degree in the shortest possible time and is sometimes willing to disregard all other

considerations, including the quality of his education, to achieve this. Nevertheless, the adviser should make certain that the student has a very solid working knowledge of the basic subjects before he permits him to enter upon the advanced phases. By now, many of the larger physics departments have " experts " on the staff who have dealt with many foreign graduate students, but even then, dealing with some of these cases might require an inordinate amount of time which the adviser, himself a working research scientist, is not willing to give. A judicious allocation of such foreign graduate students among those in the department who realise the problems involved might in some cases " save " students who, if left without special supervision, would fall by the wayside.

Once the student has completed his work towards an advanced degree and received his diploma, he is confronted with the question of whether to return home or not. This is one of the thorniest problems, which will be solved only when postgraduate education on a high standard is established in the developing country itself. In the meantime, there are various measures that should be taken to encourage the young Ph.D. to return.[2]

The most important requirement is that a young scientist must have a good opportunity for research at a respectable salary in his home country. It cannot be expected, and in fact it is not even necessary, however, that these facilities or the salary match those that exist in some places in the West. For one thing, most such scientists would not be at the leading institutions in the West even if they did not return home, and to match the facilities of second- or third-class institutions in the West is not an insurmountable problem. As far as salaries are concerned, what seems to matter is not the absolute standard of living but the standard with respect to the rest of the population. Thus a salary of Rs. 1,000 in Pakistan is a very respectable one, although its dollar equivalent in the United States would be considered quite poor. I believe it is generally true that a young man, who lived in his native country up to the age of 21 or so and then has spent four years in getting a graduate degree in a Western country, prefers, other things being equal, to return to live in his own country. By " other

[2] One of these, among others, is the education on this matter of American public opinion which at the present sees the issue from a very one-sided point of view. It is not entirely uncommon for a well-qualified young scientist from a developing country, upon receiving his degree in the United States, to seek the help of newspapers and other information media to obtain permission to continue to stay in the country. The case is usually described in terms of a brilliant young scientist whose skills are greatly needed by the United States, whose training would be completely wasted in his homeland, and who might even be persecuted upon his return to his native country which is described as ruled by a non-democratic government. It is claimed that the United States Immigration and Naturalization Service, because of its bureaucratic outlook and cumbersome procedures, forces the poor student to leave the United States. Sometimes, for local political reasons, a congressman enters the case and the deportation is delayed, often long enough for the student to marry a young American woman, in which case the matter is settled. I believe that if the other side of this coin were explained to the American public in greater detail such incidents would be less frequent.

things being equal" I simply mean adequate research facilities and adequate financial support in the above sense.

Often the student from the underdeveloped country who wishes to stay abroad is not "brilliant" enough to be really in great demand in an advanced country, but his competence could be very valuable in his own country where persons with his kind, quality and amount of training are few and where his own prospects are, therefore, greater. One of the really exciting aspects of life in a developing country is that there a single person with good training and much energy and determination (and, of course, some support from the local leadership) can have a tremendous impact on the country as a whole. In the West, where well-trained, highly intelligent people appear in great numbers, most of them have to be contented with making themselves felt only on a rather microscopic scale. It is therefore in the best interest of everybody (including the scientist in question) if he is given an opportunity somewhere where his contributions can be maximised.

It has sometimes been a practice of governments of developing countries to require a bond from the student just about to be sent abroad, guaranteeing his return after he has received his degree. I do not think this is a good practice. For one thing, it simply does not work, since the bond is small enough (*e.g.*, $2,000) so that if the student did stay in the West, he could pay it off within a short time without prohibitive sacrifices. Secondly, such a bond establishes a rather strange relationship between the student and his home country, in which the former's obligations are expressed in purely financial terms. An alternative method would be for the Western scientist who arranges the admission or the head of the department to which the student is admitted to ask the student for his word of honour that he will return to his country for at least two years after getting his degree. This obligation could still be changed if really unusual circumstances arose but it would make the whole matter a part of the personal relationship between the student and a Western scientist, something that would undoubtedly appeal to many students.

Overcoming Intellectual Isolation

Some of the problems which face working research scientists in developing countries were discussed in my first article. The most important handicap of a scientist in a developing country is his relative isolation from contact with other scientists. The inferiority of physical facilities, although an important factor, is definitely less crucial and also much easier to remedy. I would like, therefore, to suggest five ways in which the isolation of these scientists can be relieved.

The first of these might be to grant rather frequent sabbatical years at

Western research centres. It is not unreasonable to expect that, in order to function near his capacity, a scientist in a developing country should spend one out of every three years in the West. The problem here is twofold, first to find positions for these scientists and second, in view of the market for scientific skills in Western countries, to dissuade institutions in those countries from trying to lure these scientists away from their own countries on a permanent basis. With respect to the former, one of the difficulties in finding a temporary position for such scientists is the same that arises with gaining admission for students at graduate schools: the lack of reliable references. As in the case of the students, the best type of reference is the one established by personal contact. This in turn can be brought about by increased travel of Western scientists to research establishments in the developing countries and by increased participation of scientists from the developing countries at international conferences, summer schools and other research meetings. Many universities in the United States have by now developed a considerable tradition and interest in offering temporary appointments to scientists from developing countries, but much more needs to be done, possibly with financial assistance from the United States Government. A significant step in the right direction has been the recent establishment of the International Centre of Theoretical Physics in Trieste, Italy, which is heavily slanted towards the temporary accommodation of scientists from developing countries.[3]

A second specific step could be the establishment of foreign-financed regional research centres with a significant number of foreign scientists on the staff. Although participation in such international centres might be hampered by local political considerations, the equitable distribution and impartial direction of such centres could be arranged under UN or other auspices. For example, two such centres in physics (one in Pakistan, and one in India, one specialising in solid state physics, the other in atomic and nuclear physics) would benefit not only those two countries but several others in that part of the world who, at present, are too undeveloped to do much on their own in scientific research. Such a centre would have all the advantages of being *in situ,* thus catalysing the scientific life of the region considerably beyond the primary effect it might have on the few scientists on its staff.

The third improvement involves the visits of foreign scientists to the research establishments in developing countries. (Since I dealt with this point at some length in my first article, I will not discuss it here in more detail.)

The fourth field where help can be provided has to do with written contact with the rest of the scientific world. The matter of books and

[3] *Cf. Minerva,* III, 4 (Summer, 1965), pp. 533–536.

journals was discussed in my first article. But in many branches of science (including the one I happen to be working in, namely elementary particle physics) books and journals are more and more relegated to being a depository of completed research for the purposes of later review or for access by later generations. The current research results, the "breakthrough", the "hot arguments" are propagated by conferences, personal letters and, above all, "preprints", which are rapidly duplicated copies of research papers, just completed, which might appear in journals six or 10 months hence. The distribution of these "preprints" is often done rather haphazardly and there is a tendency to flood well-established persons at leading research centres while omitting altogether little known scientists in less famous scientific establishments (who often need the preprint most). A new programme, soon to be put in operation, will centralise the duplication and distribution of such preprints, at least in high energy theoretical physics, and will send them to any group of scientists working in this field anywhere in the world, free of charge. Such a programme in other branches of science would be of great value in stimulating research in the developing countries. It is difficult for anyone not engaged in research in the pioneer fields of science to appreciate the psychological uplift and increase in research effectiveness brought about by the knowledge that vital information reaches the research worker simultaneously with those in the advanced countries.

Finally, cooperative research between Western and other scientists might also stimulate the scientific life in underdeveloped countries. A young scientist, returning home after recently obtaining his degree, often lacks the perspective to choose interesting problems to work on. But even for more experienced scientists, a congenial colleague interested in the same field is often lacking. In such situations, cooperation with a Western scientist on a certain research project might be very useful. Communication is possible by mail, although, of course, this is not at all as effective as personal contact. Such cooperation is clearly more feasible in theoretical research than in experimental work. It requires a certain amount of time on the part of the foreign half of the team, since writing out everything on paper is often time-consuming, but the rewards are often gratifying.

As I mentioned at the beginning of this section, the problem of physical equipment is also an important one. I would simply like to repeat here the suggestion made in my earlier article that a very significant improvement could be made in the efficient use of already existing equipment in the developing countries by establishing a programme of roving Western technicians, well equipped with spare parts, who would make sure that a $10,000 piece of apparatus does not lie idle for six months for the want of a 10 cent part and the know-how for its replacement.

Conclusion

Some of the above suggestions, if implemented, could contribute substantially to the stimulation of scientific life in the developing countries. In conclusion, however, two general points should be emphasised.

The first is that all the measures recommended above require patience and perseverance. It seems to be true that the less developed a country is, the more conservative its people are and the less amenable they are to changes in their lives and habits even if, from an " objective " point of view, such change is clearly " to their advantage ". The most important barrier to cross therefore when trying to contribute to any aspect of the development of an emerging country is to conquer the apathy, the inertia and the lack of urgency that generally prevails. Usually a few talented, visionary and energetic local figures will work hard at bringing about such changes but the results will be sometimes uncertain and almost always slow to emerge. That such slowness is in the nature of things is important to realise in order to avoid the disillusion and demoralisation that I have often seen among Westerners working in the developing countries and even sometimes among the more enlightened local leaders. But coercive methods can do nothing, and least of all in scientific research. A middle road can be found which accepts and seeks slow but steady change, fast enough to make considerable progress in the long run but not so fast as to make whole generations of people permanently miserable and insecure.

Finally, it must be stressed that the most important general factor in the success or failure of the scientific life of a developing country is the morale of its individual scientists. I have seen over and over again scientists from those countries, who worked hard and produced interesting results while staying in a Western country, falter and fail when returning home to research conditions which were by no means worse than those they had in the West. Partly, it might be the influence of the environment, the sight of too many people sitting around in the streets, doing nothing. Partly, it might be a secret conviction that it is just impossible to do research in an underdeveloped country. In part, it might also be due to their private life in a society whose standards, mores and values are different from a modern industrial society. In any case, it is primarily a psychological problem and, as such, might often be contrary to the norms of a " rational " analysis. At the same time, small and objectively speaking insignificant factors can often cause great improvements in the morale of a scientist in a developing country. An invitation to a conference, a Western visitor for a week, a joint paper with a Western scientist, being placed on the list of those who receive preprints, or even repeated reference in the literature to work done by him all contribute towards dispelling the feeling that he is

excluded from the community of scientists, that he is cast out into the darkness where the handicaps are insurmountable. These are all steps that are easy to take but are often not thought of because their significance is not appreciated. And yet, in the last analysis, it is the enthusiasm and high morale of the leading individual scientists that will determine the rate of scientific progress in the emerging countries and hence will decide whether the gap between the advanced and emerging countries will continue to grow or whether it will begin to close.