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M. I. T. CENTENNIAL CONFERENCE

SUMMARY OF TOPIC A

Some Problems of Scientific and Engineering Education in Newly Developing Countries

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I'd like to start by trying to give those of you who have not participated in the conference which has just concluded some notion of the difficulty of the task that confronts the four reporters this morning. My assignment is to summarize for you in half an hour four days of concentrated discussion of the problems of scientific and engineering education in newly developing countries. This discussion was carried on by some thirty-eight distinguished people from eighteen countries representing the principal continents. Included were four university presidents, numerous deans and heads of departments, government officials responsible for scientific and technical education in their countries, and representatives of the principal disciplines of the natural and social sciences and engineering. I took 71 pages of notes.

I am gored by the horns of a dilemma. On the one hand, if I try to list all the important points that were made, I will fail to convey the content of any of them. On the other hand if I give you my impressions of what I would select as a few of the most significant of the ideas developed, this will inevitably be strongly influenced by my own tastes and convictions. And there is always the possibility that I will fall into the trap so eloquently described by Lewis Carroll in "The Hunting of the Snark":

> "...the Judge said he never had summed up before;
> So the Snark undertook it instead,
> And summed it so well that it came to far more
> Than the Witnesses ever had said!
>
> When the verdict was called for, the Jury declined
> As the word was so puzzling to spell;
> But they ventured to hope that the Snark wouldn't mind
> Undertaking that duty as well.

It was not a purpose of this conference to arrive at a verdict, or indeed at agreed conclusions. The best I can do is to try to give you some notion of some of the principal issues raised and report a few of the views on which there appeared to be substantial consensus.

First a general comment which applies to a great deal of the discussion. Over and over again we tried to pose for ourselves alternatives, choices as to which of two policies or strategies the underdeveloped countries should follow in designing their scientific and technical education, only to conclude after vigorous debate on both sides that the dichotomy was a false one, that both policies or strategies were essential for rapid development. We discussed whether it was better to concentrate the available resources on bringing a small number of the most qualified people to a very high level of professional competence comparable to the best to be found anywhere in the world, or to increase by a small margin the scientific awareness and technical proficiency of a large fraction of the population. We debated at the frontiers of new knowledge to the problems of development or whether what was most needed was rather the transfer of familiar technology from the advanced to the less developed parts of the world. We considered whether an increase in the numbers of senior professional scientists and engineers was more urgent than an expansion in the supply of technicians, craftsmen, and helpers and assistants. We talked about whether what the less developed countries most needed from the advanced countries was large-scale financial help or the kind of assistance that could only be supplied by sending out much larger numbers of first-rate people. We argued whether scientific competence could best be raised

in the underdeveloped countries by sending students abroad for training or by developing better institutions at home in which they could be educated.

In every case, as I shall explain in more detail presently, the proponents of each extreme position came round to the view that both courses had to be followed. In view of the hard fact that the total resources of the underdeveloped countries are extremely limited, two conclusions emerged with overwhelming force. First, it is urgently necessary to apply the best and most imaginative thinking to ways of improving by orders of magnitude the efficiency of the educational process at all levels in the developing countries. Second, the job simply cannot be done without major assistance from the technically more advanced to the technically less advanced parts of the world.

The development of scientific and engineering education of a modern type requires large resources which many times cannot be provided by the country itself, and therefore foreign aid will be necessary if the development is to be carried out. The scale of effort required in total throughout the world is very much larger than has been recognized. These two themes recurred and interacted throughout all of our discussions.

Beyond this, we found generalization about the problems of the underdeveloped countries singularly difficult. While it is a characteristic of virtually all underdeveloped countries that more of almost everything needs to be done, the precise mix of needs varies enormously from country to country.

The problems of various geographic areas are so diverse that quite different action must be taken, for example, in Asia, in Africa, and in

Latin America. In this connection it can further be stated that action does not depend on the availability of money alone. Within any one group, really effective action depends on the efforts of able and dedicated people who are aware not only of the needs of a particular newly developing area, but of the hidden as well as the obvious potentialities in the rest of the world. Further discussions by such groups of people of the needs of particular areas are greatly to be encouraged.

On the false issue of quality versus quantity in scientific and technical education, it was generally agreed by the panel that to develop a scientific and technical tradition adequate to its needs every underdeveloped country requires one or more high-level institutions conducting research and advanced training at standards worthy of international respect. Only through such institutions can the best brains of the country be attracted into scientific careers, kept at home to serve the national interest instead of emigrating, and be available to raise the quality of university teaching. Also the growth of such institutions in the early stages of development greatly facilitates attracting to the country from abroad top quality scientists to help in the development of the country's own human resources.

On the other hand, the development of a scientific and technical tradition cannot be accomplished by high-level university teaching and research alone. There also must be provision for the training of technicians and craftsmen and, indeed, a broad infusion of science and technology into elementary education. A drastic change in traditional ideas of elementary and high school education is required today and the underdeveloped countries need it urgently, sometimes more urgently than

developed ones. In countries in which the prevailing popular view of natural phenomena is that they are arbitrary, capricious, and beyond human control, an early exposure to the concepts of cause and effect and the manipulability of nature by man is a necessary condition for the development of a strong scientific tradition.

In the light of these multiple needs and the limited resources of the underdeveloped countries, the panel was agreed that much more serious and imaginative attention must be given to creative innovation in educational methods adapted to the needs of each region. At the elementary and secondary levels this deserves the kind of application of first-rate scientific minds and research resources that have recently gone into the redesign of the high school physics curriculum in the United States under the Physical Science Study Committee. At the university level the panel felt that renewed attention should be given to ways of insuring the collaboration and participation of researchers in teaching and the exposure of advanced students to research.

There was a good deal of discussion in the panel of the appropriate role of governments in this process. Here the problem is to find the right balance between the necessary planning and coordinating functions of government and the provision of freedom and autonomy to individual institutions in designing and conducting their research and teaching activities. It was agreed that each government must take the leadership in measures to create a scientific and technical tradition within the country. This includes such steps as conducting surveys which establish minimum educational needs related to the long-range economic development program of the country,

establishing national research councils of science and technology, and giving to those trained in science and technology a major part of the responsibility for carrying forward programs of a technical character. It was pointed out that in some countries the traditions of a civil service with primarily classical education still stand in the way of giving responsibility for technical decisions to people with technical training.

On the false issue of whether to emphasize basic science or practical applications, we came to recognize that there are special reasons in the underdeveloped countries for emphasizing both. People well trained in basic science are needed, for one thing, because in some fields the underdeveloped countries confront problems somewhat different from those faced by the more advanced ones. For instance, the problems of tropical agriculture and medicine are quite different from those in temperate climates. In other fields like meteorology, conclusions must be based on much less complete data, requiring a more profound understanding of the fundamental forces at work. Conditions in the underdeveloped countries are changing rapidly and only people with a thorough grounding in basic principles can react flexibly and understandingly to these changes.

On the other hand, professionals in the underdeveloped countries need more training in practical applications. Intellectuals in these countries are much less exposed by their culture to practical work with their hands, and absorb much less experience during their formative years in tinkering with mechanical contrivances than American or European boys. Further they are not supported in their work by a skilled class of artisans and technicians, and must be in a position to train their own helpers and assistants.

A point that the panel felt was inadequately recognized is that even where the problems are primarily those of borrowing technology from the advanced countries rather than creating it anew, the process of adapting modern scientific and technical knowledge to new societies calls for bold and creative minds. Intellectually the task of 'adapting' is as demanding and exacting as the task of initial creativity. Until it is widely recognized that adaptation calls for such creativity, the efforts made to develop the new countries will probably not be adequate for the task. Scientists in the advanced technology countries must join with those in the new ones in massive creative efforts in which there is a full recognition and respect for the problems of creative adaptation.

Again, the fact that resources cannot be concentrated on either training in basic science or on practical applications but must be devoted in large measure to both underlines the need for a critical examination of the efficiency of the educational process in each. If the need for both kinds of training in the same individual is met primarily by extending the period of formal education, the costs of education get out of hand and the jobs which must be done in the underdeveloped countries simply will not get done, because people are in school too long before they become useful to the society. The panel felt that this suggested renewed attention to the possibilities of on-the-job training. This has a number of dimensions.

In the first place, basic education should give more emphasis to imparting the learning process and less to the acquisition of

specific information. If people learn how to learn early, and are given frequent opportunities during their careers to renew the learning process, they can be started on productive careers earlier without sacrificing ultimate professional depth. Secondly members of the panel cited instances in which crafts and skills had demonstrably been acquired a good deal more rapidly through properly designed programs of apprenticeship than through formal vocational training, though some of the latter is certainly required.

One panel member called attention to the need to pay special attention to a human resource whose professional potential is underutilized in many countries, namely women. A good deal of resources are invested in the education of women, many of them in scientific and technical subjects, but the learning process is interrupted more or less permanently and their professional productivity disappears because family obligations draw them entirely out of productive employment for a number of years. Such efforts as have been made in some countries to provide incentives for and conditions of part-time employment for women which will permit them to discharge their family obligations have suggested that much more could be done along these lines.

Two other problems of scientific and technical education peculiarly acute in underdeveloped countries were considered by the panel. The first is the problem of scientific language and terminology. In most of the underdeveloped countries there is little or no scientific literature in the native language and there are not even terms for many of the concepts of science. This poses a double problem. First for elementary levels of instruction appropriate language must be devised

for teaching the principles of science in the native tongue and textbooks and other materials must be provided. Second for advanced instruction, it is impractical to contemplate translation of the range of literature which must be familiar to an advanced student, and the student must therefore learn Russian, English, or a European language in order to progress. The precise point in the educational process at which the shift to a second language is most desirable is debatable, but wherever it occurs the language problem imposes an added cost in both time and resources on scientific and technical education in the less advanced countries.

The other problem which complicates the problems of scientific and technical education in the developing countries is the intimate relation between scientific and technical change on the one hand and social, cultural, and moral change on the other. The introduction of technical change in a traditional society runs into obstacles of a social and cultural sort which the local scientist and engineer must understand if he is to avoid deep frustration. The introduction of new agricultural techniques into a rural peasant community or the adaptation of factory machinery to the outlook and capabilities of a non-industrial labor force requires an explicit understanding of the characteristics of his own culture which the man trained only in his professional discipline will not have. Beyond this, when new technology is introduced into a society, a chain of social and political consequences is frequently set in motion of which it is important that the scientist or engineer should be aware.

He needs both an understanding of these non-technical consequences of technical change and some sense of social responsibility for them. Several panel members underlined the importance of somehow imparting to the new professional middle class being created by scientific and technical education a deeper and more social set of values than the pursuit of income, prestige, and power. One member pointed out that the U. S. and British professional middle class emerged during a period in the nineteenth century when there was a climate of Puritan values that strongly conditioned the outlook of the professional. He doubted whether there was a comparable set of forces at work in contemporary society. The panel agreed that efforts must be made to impart to the engineer and the scientist an awareness of the social consequences of changes caused by science and technology and of his responsibility to the community for these changes.

A related point has to do with the need for training at least some scientists and engineers in the problems and techniques of management, either as part of the formal educational process or through job experience. In the advanced countries there is, in general, a substantial separate pool of managerial and administrative talent to whom the professional scientist and engineer can look for the effective implementation of his ideas. In the underdeveloped countries this is frequently not present and the professional without administrative skills is likely to find his efforts to improve conditions frustrated by difficulties of execution. The panel agreed that attention must be given to the development of the managerial skills necessary for the operation of technical enterprises.

The panel's discussion of the problems of assistance from the richer to the poorer nations in matters of scientific and technical education began with another issue which I think most of the participants came to feel was a false one before we finished our deliberations. This was whether the most urgent need was money or people. Almost everyone agreed that considerable amounts of money--probably more than has been made available in recent years--were required. For one thing, scientific and technical education cannot flourish unless the whole educational system of which it is only one aspect is adequately supported. For another the educational systems of the underdeveloped countries are increasingly being devoted to the modernization of those countries, a process which has necessary components of industrialization, expansion of transport, power, and communication, and transformation of agriculture which require external financial resources much larger than those needed for education itself. There was a feeling among some members of the panel that scientific and technical education could not flourish unless the other more costly aspects of economic development were also being supported on an adequate scale.

Even confining themselves to the requirements of scientific and technical education itself for outside resources other than people, the panel found some items which seemed to it of some importance. There is a great shortage in the underdeveloped countries of books, laboratory equipment, and other teaching aids and such items as are available are not priced in a range which makes them accessible to students in these countries. More economical methods of producing especially books must be found. To be accessible to professional

students, books must be reduced in price to not more than 10 per cent of what they now sell for. The panel felt that subsidies should be employed wherever improved methods cannot bring the price down by the required amount.

Adequate library facilities are an absolute requirement for scientific and technical development. Newly developing countries will need back issues of technical journals and reference books if they are to apply existing technical knowledge. A program should be undertaken immediately to provide adequate back journals and reference books by microfilm or, preferably, some more convenient form.

Requirements for facilities and equipment for the research laboratories needed to create an adequate scientific environment in the underdeveloped countries could, of course, run into considerably larger sums.

Nonetheless, while for all these reasons financial help was felt to be necessary, there were many who felt that the most critical requirement was likely to be people. People, of course, cost money, but the representatives of the underdeveloped countries stressed that money would not solve the problem. New incentives and new institutional arrangements were seen to be needed to insure that people of the right quality were made available in the right numbers for the right purposes and under the right arrangements.

In order for a foreign scientist or engineer to perform an effective job of assistance to scientific and technical education in an underdeveloped country, he must have an unusual range of talents. He must

first of all be first class in his professional field. Only under these circumstances will he have the professional respect of the best of his students and colleagues inside the country. Second he must be able effectively to transmit ideas and to cooperate with people of another culture. This requires not just teaching skill but ability to work harmoniously with and to influence local colleagues on his own level. Finally, he must have dedication to and interest in his assignment.

In most cases, if he is to do an effective job, he must commit himself in one way or another to a fairly long-term interest in the country he is trying to help. The host country would in general like to have him come and live there for a number of years. It is unrealistic to expect many to do this, but a series of short visits with continuing contact in between may be an adequate substitute. Alternatively, continuity may be provided by having an institution in the advanced country commit itself to supplying a number of people over the years in a coordinated fashion. Some panel members argue that a device which should be more frequently employed is that of the consortium of a number of institutions in the advanced country joining together to help one or more institutions in the underdeveloped world.

Such institutional commitments have the further advantage that they increase the likelihood that a university in the advanced country will be sensitive to the requirements of students coming from the developing country for higher training. The panel felt that the bulk of undergraduate training in science and engineering should be done at home but that sending advanced students abroad could complement in important ways the importation of foreign scientists and engineers.

In any case, it was felt that in order to make such exchanges fully fruitful, much more thought needed to be given to the design of the ideal institutional arrangements.

Efforts should be made to establish direct sister-to-sister relations between universities and research institutions in advanced countries and those in newly developing countries and the governments should reduce the governmental administrative procedures involved in such relations.

There should be encouragement given to the establishment of collaborative research between individuals in universities in advanced and in newly developing countries, the results of such research being exchanged by mail and by occasional meetings.

There should be encouragement of the holding of international scientific and technical conferences in newly developing countries since such meetings will do much to bring the spirit of science and technology to greater numbers of students and professionals in the country.

But the panel felt that none of these arrangements could be made effective without some changes of a more far-reaching sort.

The concept of the university must be altered to meet the challenge of an explosively changing world. Historically, the university provided a means for the lonely scholar to advance, preserve, and transmit knowledge. The size and functions of the university were largely governed by the requirements of teaching. In recent years the universities' functions have expanded greatly but without the appropriate and explicit

recognition of the need for changes in the very structure of the university. There is a need for university faculties to expand so that the university can meet all its new obligations to national and international society. Specifically, the faculties of universities in developed countries should be expanded 5 per cent to 10 per cent to make personnel available for development of education and research in the newly developing countries. For scientists and engineers to contribute to the essential development of scientific education in the new countries, changes must be made in the structure and size of its faculties. In a fundamental sense, universities are currently understaffed if these new responsibilities are to be included as part of the basic mission of universities.

Finally, the panel felt that there is a responsibility for sustained support and dedicated spirit on the part of the receiving country or organization. Too often, once funds are obtained and arrangements made for the assistance of "experts" or of institutions, attention in the host country turns to the next job and it is assumed that the first will take care of itself. The host country must see that first-rate local personnel are kept associated with the project and made to feel the importance of what they are doing. One panel member from an underdeveloped country suggested that one way of promoting this sense of responsibility would be to have all countries including those receiving assistance contribute 1 per cent of their national income to a United Nations administered development fund.

In conclusion, in the modern world, science and technology must carry an increasingly larger part of the effort required to develop countries. There is no hope of bringing a country out of an undeveloped status unless the country develops a national scientific and technical tradition.