The Role of U.S. Engineering Schools in Development Assistance

DETAILS

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Commission on International Relations
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This report is the result of deliberations by the Panel on the Role of U.S. Engineering Schools in Development Assistance of the Board on Science and Technology for International Development, Commission on International Relations, National Research Council, in collaboration with the Office of the Foreign Secretary of the National Academy of Engineering, for the Office of Science and Technology, Bureau for Technical Assistance, Agency for International Development, Washington, D.C., under Contract No. AID/csd-2584, Task Order No. 1.

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PANEL ON THE ROLE OF U.S. ENGINEERING SCHOOLS IN DEVELOPMENT ASSISTANCE

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FOREWORD

This report is one of a series undertaken under the auspices of the Board on Science and Technology for International Development (BOSTID) of the Commission on International Relations of the National Research Council, a joint agency of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The report was requested by the Agency for International Development.

The panel responsible for the report was composed of educators from engineering schools in the United States and developing countries, along with one engineer from an international technical assistance agency. Each of the panel members has had several years of experience in foreign assistance programs either at his own university, at universities in developing countries, or in most cases, at both. Together they represent a cross section of engineering disciplines.

The project was designed to obtain the informed judgments of the panelists on the future role of U.S. engineering institutions in assisting developing nations. It was not intended to be a formal research exercise. The report is based upon deliberations of the panel in September 1973, January 1974, and June 1975, and upon subsequent discussions by members of the panel. Preliminary work had been done by another panel during 1971-72.

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INTRODUCTION

Over the past 25 years, the faculties of a number of U.S. engineering schools have participated in programs to assist developing nations. The role of these educators has been to improve scientific and technical education and to act as consultants and advisers in strengthening engineering schools abroad. These efforts were supported by development-assistance agencies--principally the Agency for International Development (AID) and private philanthropic foundations--within the framework of their larger objectives to build up the economies of the less-developed countries (LDCs).

In the 1950s, a large share of aid was expended on civil works--highways, dams, ports, electric systems, and such--on the theory that strengthening infrastructures was an essential precondition to economic takeoff.

In line with this theory, programs were launched in the 1950s and the 1960s to build up LDC educational and research institutions and to train managers, scientists, engineers, and technicians. As indigenous capabilities emerged, responsibility for planning, implementation, and management of development efforts shifted from foreign or expatriate hands to those of indigenous cadres. Although Gross National Product increased substantially during this period in most developing countries, the lower income levels in most LDCs did not benefit in any commensurate way from the general improvement of economic conditions. The "trickle down" effect, which, it had been hoped, would assure the diffusion of economic well-being throughout the populations, failed to materialize. Instead, in many LDCs the gap between those in the upper income levels and the impoverished majority widened. At present, as the thrust of development efforts is being redirected to rectifying this imbalance, external resources, and in many LDCs an increasing share of domestic resources, are being targeted to aid the poor.

There is great diversity among the 100-odd nations classed as LDCs. Attainment of the new development objectives in the LDCs rests upon varying and complex political and economic factors, both internal and external. Not the least of the challenges being faced is the training of an indigenous leadership capable of dealing with a new set of difficult sociotechnical problems. It is in this area that AID has turned to the U.S. engineering education community for advice and guidance.

AID requested BOSTID to consider several questions relating to the role American engineering schools could or should play to help LDC engineering students, faculty, and institutions to participate more effectively in economic development of their countries.

Specifically, the panel was asked to consider these questions:

- What implications do the changing concepts and priorities of economic development policy have for LDC-oriented efforts by the U.S. engineering education community?
- What new or modified programs can be introduced into appropriate U.S. engineering schools to make the preparation of LDC-oriented engineers (U.S. and foreign students) more relevant to problems of LDCs?
- What new or better ways are there in which U.S. engineering school research interests and capabilities can be utilized to attack LDC technological problems such as adaptation of existing technology to different factor proportions, development of new technologies, processes, or systems?
- How can other interests and capabilities of appropriate U.S. engineering schools be better utilized to meet the needs of the LDCs?

Further, the panel was asked to evaluate the concept of the "development engineer" or "development technologist" as a new professional category combining engineering and development economics, and draw implications for training and utilization of these skills.

The report reviews the panel's opinions on a) the accomplishments and strengths of past programs and b) the key problems in current institutional and organizational approaches. Several areas of future intervention are discussed in some detail along with a summary of the panel's conclusions and recommendations.

This report is addressed to persons interested in improving engineering education and research in the field of economic development, including:

- The U.S. Agency for International Development;
- International assistance agencies committing resources to technical education;
- The deans and faculties of U.S. engineering colleges involved or interested in development assistance; and
- The deans and faculties of engineering colleges in developing nations.

The panel hopes that this analysis and the recommended courses of action will stimulate the engineering education community to create new strategies to improve economic conditions throughout the developing world.

ENGINEERING EDUCATION FOR DEVELOPMENT: OPPORTUNITIES AND CONSTRAINTS

U.S. universities desiring to assist developing nations over the next decade must contend not only with those goals that existed during the 1960s (when the principal objective was to build strong engineering institutions abroad) but with new goals as well. Developmental priorities toward programs favoring the poor are changing, and world economic conditions have undergone major upheavals because of the recession, inflation, and precipitous rise in energy costs. These have caused severe damage to the economies of all but the oil-producing nations.

The world economic downturn has raised the question of just how much financial aid and technical assistance the United States and other industrialized nations will commit to the LDCs in the foreseeable future. The generation of large new assistance programs in which American schools of engineering might be called on to participate would appear unlikely anytime soon.

However, even within a climate where assistance programs are being scaled down, there remains much that American institutions can do to help the developing countries. Today these countries are more in need of technical expertise to solve their increasingly complex problems than ever before. Generally speaking, there is continuing need for better definition of developmental priorities, for more research and development, for technological planning, and for trained engineering manpower to carry out developmental objectives within the limits of reduced financial resources.

What can engineering education do to help satisfy these diverse and pressing needs? What are the areas in which educators can intervene (in either the United States or the LDCs) to further new economic development policies? In short, where should the attention of U.S. engineering schools be focused over the next several years?

In exploring answers to these questions, it is useful to review briefly the types of activity U.S. schools have engaged in over the past two decades, and then to examine where a continuation or a modification of an activity--or an entirely new effort--appears desirable.

REVIEW OF LDC-RELATED ACTIVITIES

Engineering Education

In the post-World War II era, most U.S. engineering schools became host to thousands of foreign students seeking technical training. At first, the majority of the students were undergraduates. By 1965, one survey showed a total of 18,094 foreign engineering students--with 9,754 listed as undergraduates; 7,733 as graduate students; and 608 in an "other" category of special students.* In recent years, the training of undergraduates from other industrialized countries and from the LDCs has slowed down. In the LDCs that role increasingly has been taken over by engineering colleges that were created or modernized during the institution-building phase of foreign assistance. However, because universities in developing countries, for the most part, are still lacking in graduate-level programs, U.S. schools (along with institutions in Western Europe and the Soviet Union) are still educating many LDC graduate students. Currently, it is estimated that approximately 25 percent of the graduate students of U.S. engineering schools are foreign, a large share from LDCs.

A long-standing dilemma associated with the training of foreign students is that a high proportion choose to remain in the United States, joining industry or taking teaching positions, rather than return home where their talents are obviously needed. A major factor, of course, is that employment opportunities in the LDCs commensurate with their advanced skills and training generally are still quite limited, particularly for those graduates who can compete effectively in the world market for engineers.

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*Education and World Affairs, <u>The Professional School and World Affairs: Report of the Task Force on Agriculture and Engineering</u> (New York: Education and World Affairs, 1967), p.2.

Of immediate concern to U.S. engineering schools is the provision of training for foreign students (and U.S. students) who wish to prepare themselves for work directly related to economic development. To date, the demand for programs with this orientation has not been great. Nevertheless, the panel believes that improved study programs of this kind would be beneficial. The LDCs need people in decision-making positions able to make prudent selections of technology to meet the developmental requirements of their countries, people who will take into account the social, cultural, and environmental factors related to technological choices. Properly designed educational programs could increase both the number and effectiveness of these managers.

Institution Building Abroad

The involvement of U.S. universities with institutions in developing nations dates back to the late 1940s. But major efforts to upgrade the faculties and competence of LDC engineering schools took place during the 1950s and 1960s when AID and major American foundations began sponsoring a number of programs that sustained a variety of institutional relationships. Members of the panel were personally involved in many of these programs, some of which are cited as examples in this report.

The basic objective of these programs was institution building and the production of trained manpower; there was as yet little concern about favoring excessivly the urban elite or the impoverished masses. The assumption was--and probably remains valid still--that economic and social development is more likely to occur if the population includes an adequate number of competent professionals in the various fields of engineering. AID alone spent more than $100 million on educational programs during this period. There has not been a serious evaluation of the success of this investment, assessed both against its original objectives and against the new development priorities.

Representative of many of the smaller university projects was the development of a new college of engineering at the University of Gadjah Mada at Jogjakarta, Indonesia. Under an eight-year contract that began in 1957, faculty members of the University of California at Los Angeles worked with the Indonesian faculty in devising teaching methods, planning curriculum, supplying needed laboratory equipment, and providing books for the library. Some of the

Indonesian faculty were trained for a period at UCLA. The program resulted in the founding of what is now a well-established educational institution.

The University of Wisconsin headed a large cooperative project, involving several U.S. universities, to increase the enrollment capacity, modernize the curriculum, and update the mechanical and electrical engineering departments of several engineering schools in India. The program, which lasted 12 years, included the establishment of regional centers to train engineering teachers at the M.S. level so they could staff the enlarged schools. Training programs were conducted for Indian school department heads; a number of summer schools were held for Indian teachers.

The most recent phase of the U.S. program in India was the formation of a consortium of U.S. institutions to assist the new Indian Institute of Technology (IIT) at Kanpur. The American Society for Engineering Education furnished a team to do a feasibility study and to propose a plan for the development of the institution patterned on major U.S. engineering colleges with a strong science-based curriculum, graduate and research programs, and short courses for industry. The team contained one person who had served on the Wisconsin team, and drew upon the experience of the University of Illinois, Michigan State University, and the University of Wisconsin in formulating the proposal and recommending contract provisions. In the period 1962-1972, IIT, Kanpur, bacame a leading engineering institution, attracting an outstanding faculty, many of whom had received their advanced education in the United States.

The underlying philosophy of the institution-building program of U.S. engineering schools was to nurture an active, indigenous engineering profession able to serve the technological needs of the developing countries. It may be too early to prove or disprove the overall effectiveness of the effort. A few countries have readily absorbed the graduates of their colleges into industry and government, while others have not. In some countries, enrollments have exploded, but their economies have not yet been able to absorb and utilize the graduates.

It has been said in criticism that the graduates of some LDC engineering colleges are ill prepared to work in domestic industries because they lack practical experience. LDC domestic industries, by and large, have not been able or been accustomed to train newly graduated engineers on the job to the extent that is common in the United States.

Another criticism is that engineering graduates--like LDC medical graduates and other professionals--generally do not return to settle and work in their home districts after attending an urban university. Because there is a scarcity of attractive employment opportunities in provincial or rural areas, they are more likely either to remain in the capital city or to move to another country to pursue their careers.

Regional Centers of Graduate Study and Research

An important and sometimes overlooked part of the institution-building phase has been the strengthening of regional centers of quality graduate engineering education and research. They stand as a valuable bridge--both geographically and culturally--between the institutions of lower-income LDCs and the industrially advanced countries. Two examples of regional centers familiar to the panel are the Asian Institute of Technology at Bangkok, Thailand, and Mexico's Monterrey Institute of Technology and Advanced Studies.

The Asian Institute was created by members of the Southeast Asia Treaty Organization (SEATO) in 1959. At present it is operating as an independent regional institution with an enrollment of 300 graduate students drawn from all parts of Asia. The staff is well paid and the institution has been able to attract highly competent professors from around the world.

In research, there is an emphasis on regional problems such as the development of rivers, housing, tropical wastewater treatment, tropical soils, transportation, and related urban problems. Although the research topics are related to LDC problems, the research techniques are of a technical caliber as high as would be employed by researchers at a top engineering school in an industrialized country.

The great majority of the graduates remain in the region, usually in their home countries where many are rising to positions of responsibility and influence.

Monterrey Institute, started in 1943 by a group of local industries, has received financial help from the Ford Foundation, the Mexican Ministry of Public Education, and the Inter-American Development Bank. The staff has had graduate training abroad, and, as of this writing, of the 100 full-time faculty, 25 have doctorates and 40 have masters degrees. The majority work full time, unusual in Latin American universities. The institute offers 10 masters programs in various fields of engineering. Plans call for offering doctoral programs in the near future. More than 400 students from 18 countries in Latin America and the United States attend the school.

The Ford Foundation has provided funds for students from the region to attend Monterrey if the advanced degree desired is available there, rather than sending them to the United States or Europe to study. The institute has had a program of financial assistance for faculty members of other Mexican engineering schools who can obtain advanced degrees there while remaining on salary from their home institutions. Most of those who have entered this program have returned to their teaching posts. Research projects sponsored by the Government of Mexico at the institute are currently increasing in volume at a rate of 15 to 20 percent a year.

Another center of interest is Brazil's Institute of Space Research (INPE) at São José dos Campos near São Paulo, which started in 1963 as a research and development laboratory, and in 1968 launched a full-scale graduate program. The institute's scientific personnel numbers 1,000 today, with operations in five locations. This institute is interesting on several counts, among which are:

- It illustrates the feasibility of a research laboratory adding an educational role. This transition from a research to an educational function has happened often in the United States where an industry or governmental laboratory has both persons in need of advanced education and others qualified to provide it, coupled with a lack of nearby educational institutions with suitable part-time programs. At INPE, graduate courses are offered to Brazilian and other Latin American students in the space sciences, electronics, applied computation, systems engineering, remote sensing of earth resources, and educational technology.
- It demonstrates that sophisticated advanced technology can have relevance to a developing nation. Space technology used for weather forecasting, earth-resources monitoring, communication, and educational delivery systems show high potential not only in countries like Brazil but in India, Indonesia, and elsewhere.

Regional centers of graduate study and research are performing valuable work. For the LDC student they offer reduced costs and require less time spent in language preparation. In research they are close to LDC problems and can work on them at lower costs than are possible in the United States. Unfortunately, there are not enough of them, nor is the level of funding sufficient to attack many of the developmental problems faced by the LDCs. Some of the centers are located in countries that no longer qualify, by virtue of their economic progress, for U.S. assistance. As a consequence, their "bridging" value is inadequately recognized and their potential remains to be exploited.

Programs in U.S. Institutions

For some time now, AID has provided grants to universities to create centers of expertise that focus on various aspects of the development process. Designated as AID 211(d) grant programs, these draw on faculty and student interest in development and usually involve a combination of research, courses, and field work. The purpose of the grants is to create centers of competence that will provide research findings relevant to LDC problems as well as trained students and a cadre of faculty able to serve as resource personnel and consultants to major government and international agencies concerned with development. Until recent years, 211(d) grant programs were directed almost exclusively to such areas as agriculture and basic literacy, and they have featured topics such as agriculture, nutrition, and primary education. Neither the 211(d) programs nor other development-related research grants were directed toward the engineering disciplines, so that the level of research in U.S. engineering schools addressing development problems has been very modest.

It was not until 1971 that AID's Office of Science and Technology (AID/OST) began to make five-year 211(d) grants to leading engineering institutions. There are three at present: Cornell University, the Massachusetts Institute of Technology, and the Georgia Institute of Technology. The Cornell program, interdisciplinary in nature, focuses on science and technology policy applied to the development process. It has concentrated in subjects such as housing for low-income families, low-cost roads, the competitive position of foreign versus indigenous light industries, and the application of science and technology to regional development in relatively small developing countries. The MIT program is concerned with the adaptation of industrial and public works technology to the conditions of developing countries. Investigations range from creating evaluation frameworks for multi-modal transportation infrastructures to considering the adaptation of capital-intensive construction methods to labor-intensive environments, and from developing a technique for using electromagnetism to prospect for subsurface water in arid regions to a study of the efficient use of fibers for manufacturing purposes.

Georgia Institute of Technology is one of a few American engineering institutions engaged in industrial development in a number of LDCs. Its Industrial Development Division of the Engineering Experiment Station (recently redesignated the Economic Development Laboratory) was created in 1956 initially to help shore up Georgia's diminishing agricultural economy with new small- to medium-sized industries. The division has since branched out into developing countries, with services covering the entire spectrum of industrial and economic development, and activities ranging from basic research to applied technology.

Projects have included both training and field assistance in establishing a university-connected industrial development center in Venezuela and a research institute in Brazil, training programs for the staffs of development organizations from approximately 20 countries, and working with developmental organizations to stimulate the growth of small industries in Korea, Brazil, Ecuador, the Philippines, and Nigeria.

OPERATIONAL CONSTRAINTS ON ENGINEERING SCHOOLS IN DEVELOPMENT ASSISTANCE

Financial

U.S. colleges of engineering derive their financial support from a combination of private endowments, public subsidies, and students' tuition and fees. U.S. educational programs are necessarily directed toward filling engineering manpower needs in the United States. Thus, to implement and sustain major engineering curricular or research programs directed toward the field of international development requires a substantial infusion of funds from the international development community. We know from the experience of the past 25 years that both the direction and content of engineering-school research is influenced by the availability of funds from a sponsoring source. Major agencies such as the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD) have strongly influenced research in colleges of engineering, not by control but by supporting work of mutual interest to the agency and the school. They have attracted faculty and graduate student interest and effort. Virtually none of this research support from the agencies named has been directed toward the process of development and the adaptation of new or existing technology to the needs of the LDCs. Although AID has helped institutions initiate some research under 211(d) grants, the level of support has been too small to attract and maintain viable programs.

Policy and Procedure

In the past engineering educators working overseas have often found it difficult to satisfy the conflicting objectives and regulations of the host government, the host university, the funding agency, the home university, and the U.S. Government. For example, U.S. faculty at an LDC university have often been limited to teaching, without opportunity for research or participation in the development process. Contract interpretations and approvals vary with time and circumstances, making it difficult to plan and carry to completion well thought out programs. Further, lack of funding continuity has been a source of frustration to U.S. engineering institutions, causing them to be guarded in the extent and duration of their commitments. These factors introduce an element of instability and uncertainty into relationships that can thrive and be of long-lasting benefit only in an environment of mutual trust and long-term commitment.

Faculty

Because of the constraints described above, U.S. universities have experienced difficulty in enlisting the services of well-qualified faculty for educational programs abroad. Foreign assignments of two years or more--typical of past arrangements--are major diversions from the central mission of the home institution; a professor may have to suspend or forsake research and graduate programs that took years to construct. University administrators have few ways of evaluating the quality of faculty work done abroad and of crediting it toward promotions. Often the LDC assignment involves more teaching than the pursuit of research. And the applied research available may be quite primitive, with few opportunities to publish. Thus, many well-qualified faculty members have preferred not to become involved in a situation where the normal university and peer rewards are absent. There are a number of ways to overcome these difficulties (e.g., through more use of short-term U.S. faculty assignments, or development of joint research with LDC faculty) as will be discussed below.

TECHNIQUES FOR TRANSFERRING ENGINEERING KNOWLEDGE

Only a limited number of techniques for transferring engineering knowledge to the developing countries are currently in use. Some practices employed in the United States could be used effectively by LDC institutions for the actual application of technology to the needs of the people in those countries.

The LDC engineering colleges themselves have not been notably successful in transferring technology to the people for a number of reasons--some financial, some because of restrictive government policies, and some because of lack of proper organization. Absence of linkages with the users of technology and a preoccupation with classical or theoretical engineering education serve to isolate the LDC professor from the world around him where developmental activities are taking place.

Extension Service

Although agricultural extension has a long history in U.S. universities, only a few have developed similar relationships with the U.S. industrial sector. These have extension services to help the development of new industry; they conduct engineering clinics, workshops, seminars, and offer continuing education programs and short refresher courses. It should be noted that financial support of industry and state governments has been essential to the promulgation of these programs. It seems possible that this "extension" approach could be transferred to LDCs with beneficial results. Various models of industrial extension services should be studied and tested.

Engineering Technology

Industries in developing countries are not alone in desiring to employ new engineers whose education has placed greater emphasis on practical than on theoretical knowledge. Many employers in the United States are similarly disposed and, as a result, a new type of education program--engineering technology--has taken hold in this country. Indeed, it has become one of the fastest-growing forms of technical education in the past decade.

Two- and four-year engineering technology programs stress the application of technology rather than the theoretical and scientific aspects of engineering. Courses are oriented toward civil, mechanical, industrial, and electrical engineering and generally include course-related work experience with industry.

This new orientation, the purpose of which is to educate students in solving immediate problems, appears to be highly relevant to the situation of the developing countries because too often their engineering schools have been modeled on western, science-based institutions. The transfer of engineering technology education to the LDCs should be encouraged.

Cooperative Work-Study Programs

Many LDC students emerge from engineering colleges in their own countries and from graduate training in the United States with little or no practical work experience--a factor affecting their employability in their homelands. One remedy is the incorporation of work-study programs with cooperating industries and businesses in undergraduate and graduate LDC curricula.

Several U.S. engineering colleges for many years have offered "co-op" programs. But because their time in this country is limited by visa regulations, foreign students usually cannot avail themselves of these work-study opportunities. Co-op programs in the LDC engineering colleges may be limited in some countries by the lack of industrial work opportunity. A potential resource for work experience in the LDCs could be the locally-based U.S. multinational corporation, which might offer its cooperation as a contribution to the development of the host country. A number of multinational companies sponsor applied research and development projects in LDC institutions; they also train employees of LDC suppliers and vendors. These relationships could be expanded to include student work-study programs.

In formulating technology-based development projects, assistance agencies should consider including work-training opportunities for local engineering students. Provision could also be made to encourage the employment of young engineering trainees in engineering firms receiving overseas contracts, or the creation of internships in large U.S. consulting firms engaged in development work abroad.

Institutional Relationships

The "sister school" relationships used in the past between U.S. and LDC institutions need reexamination as instruments for future programs. The panel is of the opinion that the one-to-one relationship is very limiting. The drain on high-grade faculty—if it has to provide the services of 10 to 15 professors every year—is often too much for a single U.S. institution to bear.

On the other hand, the consortium approach makes it much easier for a group of institutions each to spare one or two highly qualified professors to form a team of adequate size and diversity. One drawback is that consortia sometimes have a lesser degree of continuity of personnel. However, in the founding of any new engineering-technology institutions abroad, it might be prudent to employ the consortium technique in getting them started.

Short Courses, Seminars, and Consulting Visits

The development of short courses and consulting visits in LDC engineering colleges can provide a means to attract more competent U.S. faculty to overseas programs. Where such professors are now reluctant to commit themselves to a year or more in a developing country, they might willingly go for a few weeks to work with faculty and/or students, and indeed to make repeated visits over several years. The technique could facilitate the transfer of knowledge with a minimum of disruption for the visiting lecturer. Training LDC faculty through these lectures ensures reaching many students long after the lecturer has departed.

Contract Special Training

Some American universities have been conducting special training programs, either on their own campuses or in the host country, for LDC government and industry personnel engaged in work related to economic development. These programs are carried out under contract to the host country. This mode of operation offers potential for expansion as a technique for training and retraining industrial and governmental managers on a broad scale. An important feature of the program is the certainty that the students have both the desire and an assured opportunity to use their new knowledge in development work.

Continuing Education

Many U.S. universities offer useful part-time programs to update or advance the knowledge and skills of practicing engineers. Such programs of continuing education are generally lacking in the LDCs, and should be encouraged as a means of directly strengthening the capability of current engineering manpower. Appropriate course materials need to be developed (including the employment of new educational technology) and organizational arrangements established for conducting continuing education programs through LDC universities. In Mexico, the Ford Foundation has provided valuable support to the National Association of Faculties and Schools of Engineering for offering courses to upgrade the education of engineering professors.

Regional Centers

One of the most promising mechanisms for transferring knowledge, as noted earlier, is the regional or "third country" center. In addition to performing conventional research and graduate education for students and professors from the LDCs of the region, these centers could provide special training for LDC government and industry personnel in various aspects of development. Course materials for such training programs could be designed in collaboration with U.S. engineering school faculties. U.S. institutions also could be employed to strengthen the staffs of the centers through collaborative research and advanced education on the U.S. campus.

Generally speaking, regional centers offering graduate-level instruction represent a better utilization of resources than a multiplicity of centers each attempting to serve national needs. Regional centers also foster regional thinking and this may have advantages over the long run. An existing engineering college with potential for being upgraded and expanded into a regional center may be situated in a "non-AID" country; such an institution should not be excluded from AID assistance if it can be helped to become an effective vehicle for providing the LDCs with graduate engineering training within their regions. Again, they have several advantages over sending LDC students or faculty to the United States for advanced study: education and living costs are usually lower; language preparation can be reduced or eliminiated; the cultural and technological environment is more similar to the home country; and quite possibly the likelihood of the student remaining in the region is increased.

THE NEW PRIORITIES AND ENGINEERING EDUCATION

More equitable distribution of income, rather than sheer economic growth as conventionally expressed in GNP figures, is the new objective of the international development community. Both in assistance agencies and in many developing countries, planners are devising policies to counter the tendency for wealth to be concentrated within a relatively narrow layer of society, generally urban, while poverty pervades the rest of the population.

To strengthen the rural base and to provide more jobs there and in the urban sector, ways are being sought to increase agricultural productivity and to foster the growth of new industries that are both labor intensive and oriented to the material needs and resources of low-income people.

While strategies to this end may differ in detail from country to country, they generally center on better utilization of natural resources, development of new energy sources, and the creation of new enterprises. Expensive energy, scarcity of investment capital, and low buying power, among other factors, make these developments difficult. This has prompted the call for the design of low-cost technology, more careful selection of technology targeted on specific problems, simpler technology whose use and maintenance requires little training, a "people-oriented" technology--or, as it is frequently termed, "appropriate technology."

While it is true that in most countries the choice of technology could be improved, the panel believes it is also true that American engineering educators have been sensitive to this problem. As a rule, educators have sought to instill in all their students (foreign and U.S.) a genuine appreciation of the role of engineering in meeting the needs of the people.

The question is whether engineering education should be adapted to be more responsive to the current objectives in development thinking. Does the new emphasis embodied in the concept of appropriate technology require a new kind of engineering education? Should LDC students be trained in different and perhaps less-sophisticated engineering practices in U.S. and LDC institutions to deal with problems of a different order of complexity?

This question has arisen before and was answered appropriately by a task force of American educators who surveyed the role of U.S. engineering schools in international economic development in 1965. The committee said:

> To bring less than the most up-to-date and powerful engineering skills to bear on the problems of an emerging country is to restrict severely the rate of its technological development. The problems may be old, but they deserve the most modern solutions we can find.*

In the view of the panel, nothing has occurred in the intervening 10 years to alter this judgment. Indeed, the very complexity of the problems currently facing the developing nations, for instance in energy or communication, makes it essential that the choice of the appropriate technology for any application be based on the latest methods and systems and include all available technology. A modern space satellite can be the cheapest and most reliable means of communication technology in a developing country with great distances between its centers, and such a system is now being constructed in Indonesia. Weather monitoring and certain aspects of natural-resources evaluation can also be performed better by satellites, whose data several countries (including Brazil, Indonesia, and Iran) are beginning to employ. A matter of concern at present among persons working in development is that much of modern technology, especially production technology, is capital intensive and labor saving, while LDCs experience a shortage of capital and a surplus of labor. Hence, technology that is more labor intensive is seen to be "appropriate." A well-educated engineer, however, should always use technology appropriate to the task at hand. He must have become adequately informed, however, on the whole spectrum of available technology in order to make the appropriate choices.

Changing strategies of development do not affect the basics of engineering education. At the undergraduate level

*<u>Op. cit.</u>, p.80

in every engineering discipline, the student's time is almost entirely occupied by studying to acquire a standard body of knowledge, regardless of whether the training takes place in a U.S. or an LDC institution.

At the graduate level, however, it is possible to enrich the education of students with development-related subjects. By then, some students may have acquired an interest in a career devoted to some special aspect in the development field; some may already be in positions for which additional training is required; and others may be slated by their governments for particular vocations. That students can benefit from learning about extra-engineering facets of development has been recognized by educators. Georgia Tech, Illinois Institute of Technology, Washington University, Stanford, Cornell, University of Wisconsin at Madison, and MIT have been experimenting with graduate programs that incorporate courses bearing on various aspects of development. These include economics of technological choice, including the spectrum of alternatives for planning and design, construction, and operation; as well as practical research problems, and legal, financial, administrative, and political problem solving.

Development in the LDCs is especially dependent upon the adaptation of available technology to specific local needs and conditions. Accordingly, graduate technical courses should contain materials that will help the engineer deal effectively with these special circumstances. While economic and cultural conditions vary from country to country, there are some general subject areas suitable for inclusion in graduate programs in U.S. graduate engineering schools and especially at regional centers serving LDCs. Additions to the instructional program might include specially designed courses in entrepreneurship, marketing, product feasibility and design, manufacturing techniques, resource utilization, and adaptive technology.

At the present time, the number of students who are likely to take the courses may be relatively small. Suitable programs at a few institutions should suffice. This kind of specialized instruction can be incorporated as options under existing programs. There also may be merit in universities cooperating to divide the responsibility for offering different kinds of specialized training related to development.

"DEVELOPMENT ENGINEER"--A NEW DISCIPLINE?

In view of the fact that the technological sector in economic development work has become an increasingly important field of endeavor whose practitioners often acquire a broad array of responsibilities, AID has raised the question whether engineering schools should devise a special curriculum or major to train people for the field. Should U.S. engineering schools create a new discipline of "development engineer" or "development technologist," with its own set of requirements comparable to those demanded for civil, chemical, and other engineering disciplines?

The panel believes that this would not be desirable and recommends against attempting to develop a new professional specialty. Many different kinds of engineering specialization are required in the development field and it would be impossible to combine them all in one curriculum. The proposition is analogous to one made several years ago that engineering schools develop a curriculum for "space engineers"; space, like development, is an area demanding teams of engineers from many engineering specialties, not a universal specialty. Development is an area of engineering application, one of many, and an engineer working in development should bring to it genuine competence in one of the basic engineering disciplines such as chemical, civil, or industrial.

There is no clear indication at present that manpower needs in the developing countries are such that it would be possible to employ a large number of "development engineers." But individual LDCs may view their own situation differently, and consider it appropriate to restructure some of their own engineering curricula to produce graduates with a special orientation suitable to their development needs. Even such graduates will probably function best as members of interdisciplinary teams of engineers and economists, pooling their individual expertise to analyze developmental problems and plan projects.

SUMMARY OF PRESENT AND FUTURE OPPORTUNITIES FOR U.S. ENGINEERING SCHOOLS TO RENDER DEVELOPMENT ASSISTANCE

The chart below summarizes major program areas where U.S. schools of engineering can act now and in the future to broaden and improve development-related education and research in this country and the LDCs.

Program	Conducted in: U.S.	LDCs
1. Undergraduate Engineering	Basically sound; continue to offer broad, balanced flexible programs. Suitable for students interested in development	Continue to upgrade quality
2. Engineering Technology	Well-established; suitable for students interested in development	Promising applicability; need to establish in LDCs
3. Graduate Engineering	Continuing influx of LDC students; good, long-term impact	Create more regional graduate centers of high quality
4. LDC-oriented Graduate Education	New courses, more experimentation to match specific LDC needs; co-operative efforts with LDC universities	U.S. provide assistance in developing advanced programs; develop applied research; provide faculty training at regional centers

5.	Industrial Extension Service	Develop additional models	Develop new university-based centers for transfer of technology
6.	Contract Special Training	Potential for expansion, both for schools of engineering and engineering technology	Potential activity at regional centers
7.	LDC Faculty Upgrading	Workshops and courses at appropriate U.S. universities	Short courses at regional centers and LDC universities
8.	Seminars on Special Subjects	Provide professors, experts	Conduct for students/faculty at LDC universities and regional centers
9.	Short Courses for LDC Engineers	Develop courses; provide visiting professors	Conduct at LDC schools and regional centers
10.	Continuing Education	Technical assistance in developing courses for use in the LDCs	Facilitate development and application. Need permanent activity in continuing education
11.	Research (wherever possible cooperative between LDC and U.S. universities	Development methodology and processes; development-oriented technical research; management techniques; energy; natural resources, etc.	LDC faculty work on products and processes; marketing; technology applications; housing; energy; natural resources

RECOMMENDATIONS

The most important role U.S. universities can play in present and future development is that of facilitators. They should seek innovative ways whereby their faculty and resources can perform this role and expedite the transfer of technology through LDC institutions and industries. To do this, the universities need assistance; therefore many of the following recommendations are directed at sponsoring agencies.

RESEARCH

• AID and other technical assistance agencies should find ways, especially by new funding, to increase applied research on LDC development problems at both U.S. and LDC institutions, and particularly at regional graduate/research centers. Bilateral research projects involving transnational cooperation should be encouraged. Funding agencies should adopt impartial award procedures that will assure quality research work, such as the peer review system long used by the National Institutes of Health and other U.S. agencies. Applied research programs will provide qualitative improvements in graduate education appropriate to development.

• AID should strengthen institutional capability by such means as its 211(d) program, including extension of this kind of support to additional engineering colleges. A mechanism should be created whereby a follow-through is ensured to utilize any promising results originated by research at institutions.

CURRICULUM IMPROVEMENT

• Funding is needed to improve courses and programs at selected U.S., LDC, and regional graduate centers for graduate students interested in economic development. Efforts should be made to innovate courses in appropriate areas, stressing methodologies of technological choices, systems analysis, economic analysis, environmental-impact assessment, etc. Cooperation and avoidance of duplication among universities is needed in the creation of these special courses, since the number of students may be small.

• Innovative work-study programs are needed for students at both U.S. and LDC institutions. The potential for co-op programs with U.S.-based multinational companies in LDCs should be explored by educational institutions, funding agencies, and the companies.

• U.S. colleges of engineering technology, together with funding agencies, should test the potential for this type of technical education in the LDCs.

TECHNOLOGY TRANSFER

• The concept of establishing engineering/industrial extension services to facilitate the transfer of technology, especially in rural areas of LDCs, should be explored as to feasibility and applicability.

• U.S. schools should seek to expand their contract services to offer additional special education in development related subjects to LDC government and industrial managers. The activity could be sponsored either on U.S. campuses, at LDC universities, or at regional graduate centers.

• Programs should be generated to encourage U.S. faculty members to take short-term assignments abroad in advisory and consulting capacities, and to instruct other teachers. Such programs would resolve, to a considerable extent, the problem of attracting more distinguished faculty to work overseas. Greater use also could be made of qualified instructors from local subsidiaries of U.S. corporations to teach professors and students in the LDCs.

• To upgrade LDC faculties and to keep both LDC faculties and students abreast of new technological developments, U.S. schools should develop short courses, workshops, and seminars. These courses should be given in the LDCs by high-grade visiting U.S. faculty.

• U.S. schools should provide technical assistance to LDC universities in developing continuing education courses for LDC engineers. The courses could emphasize development as well as enhance the level of knowledge in individual engineering disciplines.

EVALUATION

• Past programs involving "sister" schools and consortia of U.S. schools that assist LDC institutions should be evaluated against original objectives and the new priorities for the purpose of designing better support arrangements in the future.

• Future programs should specify an evaluation phase, coupled with clearly stated objectives.

• Consideration should be given to providing criteria and means for the evaluation of U.S. faculty performance in development assistance.

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