Science and Technology in Mexico: Toward Self-Determination

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In the modern world, a country must develop its own scientific and technological capabilities in order to progress economically. This fact was not widely understood in Mexican government circles before 1970.

The picture began to change in that year when the National Council of Science and Technology (CONACYT) was launched (*1*). By the time that the President of Mexico appointed me to serve as CONACYT's third director general in 1976, he set as a goal "the achievement of a certain degree of self-determination" in science and technology. During my tenure, in addition to making the day-to-day decisions that the progress of the council demands, I was tinkering with the mechanisms involved in planning the transfer to and the naturalization of science and technology in my developing country.

W. Arthur Lewis, winner of the 1979 Nobel Prize in Economics, has offered some pertinent advice about planning: "a plan is essentially a set of guesses about the future . . . but since there is no formula for predicting the future . . . a development plan is made in the light of a general philosophy on how development takes place" (*2*). The basic issue is understanding the behavior of the forces that lead to development. Statistical, econometric, and computing expertise is secondary. I would like to offer my own guesses and general philosophy on these matters as well as describe the route that Mexico has followed.

Naturalizing Science and Technology

Development may take place in a democracy or a dictatorship, under capitalism, socialism, or communism, but it cannot occur without a critical mass of specialists in science and technology. The political decision to develop science and technology requires shifting a considerable share of the government's expenditure to education and research over a long period.

Clearly, it is difficult, if not impossible, to regulate the rate of development. In fact, I believe, there are really only two options open in the initial stages: either to give science and technology a deliberate push from wherever you start, satisfying its growth and often unexpected demands, or else not to interfere and continue to import the habitual inputs for consumption and industry, thus condemning the country in the long run to increase its technological dependence.

Once you choose the first option, you choose a long and expensive process, subject to the possibility of failure, in which one cannot hope for shortcuts, cultural revolutions, blitzkriegs, or bargains. A formal plan at this stage is as likely to thwart as to hasten growth. But some do's and don't's should be arrived at; for instance, the mastering of the basic knowledge and technologies involved in producing enough food to feed the whole population, as well as technologies related to nutrition, public health, and birth control, ought to take precedence over heavy involvement in nuclear physics and related fields.

The only possible policy is to inject into the country massive doses of training in many fields, emphasizing engineering and the training of the labor force at the intermediate and lower levels. At this point, "small is beautiful" (*3*), and appropriate technologies are either nonsense, if taken seriously, or political diversions to attain goals of a different nature. I should note that these massive doses of training, especially abroad, of young scientists and technicians, are likely to produce unwanted side effects. Development policies will inevitably erode the foundations of traditional society and may bring forth acute resentment and opposition in the traditional centers of power. Technologies that will respond successfully to development needs will only result from a union of interests—first and foremost, those of the researcher, and then those of the institutions, private or public, that can provide the needed financial backing.

Eventually, the country's own propensities—defined by its geography, natural resources, traditions, level of development, defense needs, economic priorities, and general objectives—will indicate the areas that need reinforcement. At this point, a formal, straightforward plan may be useful.

Mexico's Science and Technology Plan

In 1977, President José López Portillo was prepared to direct more funds into research. In return, he wanted the country's scientific community to prepare a plan that would resolve two fundamental questions: What is the basic objective of scientific research in a country at our stage of development? What kind of research are we going to do with our own resources and what kind are we going to import, be it directly or through our students who study abroad?

Thus emerged the National Program for Science and Technology 1978–1982, prepared by CONACYT, with specific yearly goals for the short term and emphasis on the government's economic priorities—agriculture, public health, energy, and unemployment. (This program is part of the country's Overall Development Plan 1980–1982, which has been translated into both French and English.) The new government impetus made it possible from 1978 onward to undertake a variety of joint programs, and a vigorous, decentralized, and democratic system of decision-making has evolved. In addition to CONACYT, this sytem is formed by the Department of Public Education (SEP), the National Association of Universities and Institutes of Higher Learning (ANUIES), the universities, especially the National University of Mexico (UNAM), and many of the research facilities of other government agencies. (I will present some examples of how this system operates later on.)

CONACYT's budget has grown to nearly 4.7 billion pesos (approximately $200 million U.S. dollars, at the beginning of 1982, before the last three devaluations) and overall government expenditure in science and technology has risen 40 percent annually during the past 6 years, reaching 28 billion pesos, or 0.6 percent of our country's gross national product. In 1980, 30 percent of the proj-

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ects in the science and technology program were complete and 43 percent under way. From the beginning of the administration of President López Portillo, the oil boom made it possible, for a while, to give unprecedented support to scientific and technological research and to the training of scientists. That support has been instrumental in solidifying some of the foundation and infrastructure needed to build that "certain degree of self-determination."

CONACYT's scientifc and technological development program has also received substantial support from the Inter-American Development Bank (IDB): a $20-million (U.S. dollars) loan in 1977, with a national counterpart equal to $24-million; a $40-million loan in 1980, with a national counterpart of $24 million; and a $50-million loan in 1981, with a $75-million counterpart. It is worth noting that CONACYT has enjoyed considerable autonomy in the application of these loans, both in assigning priorities and in financing specific projects.

These funds have been channeled into the major components of the science and technology program, including scholarships, indicative programs, industry programs, research centers, and international ventures. In addition, a major effort has been made to break the isolation of much of the Spanish-speaking community by translating important works into Spanish and disseminating our work to other research communities.

Scholarships. Since January 1977, CONACYT has granted more than 18,000 scholarships, partly with IDB funds. (A total of 26,447 grants have been awarded since the founding of the council in 1970.) The infusion of these scholarship students, trained in the best research and development institutions, both in Mexico and the rest of the world, into our scientific community has already begun to give it a new structure and new perspectives. In the first 6 months of 1982 alone, CONACYT had more than 6000 scholarship students, half in Mexico and the rest in more than 30 other countries.

In order to train more students at home in the national priorities, intergovernmental agreements to promote the development of high-level educational programs, research projects, production techniques, and administrative reform activity have increased. The number of scholarships resulting from these agreements has gone from 15 percent in 1977 to 68 percent in 1981.

Although scholarships are granted according to the priorities of economic policy, the distribution of scholarships by discipline has been biased by the country's own educational system. It is not possible, for instance, to train the badly needed transport and communication technicians if appropriate courses are not available.

Indicative programs. In accordance with the law that created CONACYT, the National Indicative Programs were created to bring together distinguished members of the scientific community, the government, and the private sector in order to provide a link between CONACYT and the science and technology system. It is up to the committees managing these programs to assign priorities and to evaluate and recommend the assignment of resources for research and for the country's scientific and technological infrastructure. Currently, these committees back 600 research and infrastructure projects.

Since 1977, CONACYT's initial concern with basic sciences has been extended to applied sciences and technology. Great importance has been given to collaborating with national industry and to creating new industries. For this purpose, new indicative programs were started in energy, the chemical industry, the metalworking industry, the electricity and electronic industry, and public administration. The establishment of these programs meant considerable modifications in the council's policy of assigning resources. Instead of continuing to support almost exclusively the areas that had already become part of the country's scientific system, resources have been used to reorient the system's infrastructure in order to support these new areas. CONACYT currently has 15 indicative programs in basic sciences, agronomy, health, social studies, and several branches of technology.

An industry program. The Shared Risk Program, a financial program aimed at encouraging Mexican companies to contract research and technological development services in Mexico, was established in 1979. Through it, CONACYT and the company assume joint responsibility for projects. For example, CONACYT and the Federal Electricity Commission are jointly sponsoring a project to develop a simulator to train personnel for work in thermoelectric plants. The project, 70 percent completed, is expected to cost 115 million pesos and is being carried out by the Electrical Research Institute (IIE). It has great international relevance, and the IIE has received requests from buyers from other countries interested in the project results.

Centers for research. CONACYT participates in the creation of research centers together with state governments, institutions of higher learning, industrial groups, and other agencies. In addition to the 18 centers set up during the previous administration, five new centers were promoted in the last 5 years. CONACYT also supported 43 projects to expand existing centers and to establish new units. In accordance with the decentralization policy, 20 of these 43 projects are in the provinces.

International agreements. CONACYT is the executive agency of scientific and technological cooperation agreements between the Mexican government and other countries, and a signatory of agreements with foreign institutions such as the National Science Foundation in the United States and the Centre National de la Recherche Scientifique in France. CONACYT also serves as a liaison office for the scientific and technological development programs of international agencies such as the United National Development Program and the Regional Program for Scientific and Technological Development of the Organization of American States. At present, Mexico maintains intergovernmental agreements with 34 countries and international cooperation agreements with

Summary. During the last decade Mexico has moved progressively to develop and naturalize its scientific and technological capabilities, a decision requiring long-term government investment in education and research. The areas in which Mexico's National Council of Science and Technology selected to focus a national development program include the following: scholarships for middle- as well as high-level researchers and technicians; indicative programs to support research and basic or new industries in fields such as energy, electronics, metalworking, and agronomy; a government-industry shared risk program; research centers, many located in the provinces; and international scientific agreements. The translation of scientific classics and contemporary publications into Spanish and their widespread dissemination in Mexico have received special attention as has the dissemination of Mexico's work worldwide.

37. The largest programs are with France, Cuba, the United States, Spain, Israel, Nicaragua, Costa Rica, Brazil, and the Soviet Union. The fields covered are diverse and include energy research, food technology, mathematics, oceanography, remote sensing, public health, physics, technology management, and the development of natural products.

Disseminating Scientific Information

One aspect of CONACYT's work to which we have given special attention is the dissemination of scientific information, both of major works that have not been translated into our language [Newton (*4*) for example, was not translated into Spanish until 1977, ostensibly because it was banned by the *Index Librorum Prohibitorum*], as well as information about the most recent discoveries in science and technology.

Not to have literature on science and technology—classical works as well as contemporary publications—available in Spanish at all levels has the adverse effect of creating an elitist and alien scientific community, isolated from the rest of society because knowledge is obtained in foreign languages and cultures. The only way to keep science and technology from alienation and from ultimately becoming denaturalized is to graft them onto one's own culture, in this case the Spanish culture, the Spanish-American culture, the Mexican culture, our culture. This applies especially to the training of specialists at the intermediate level who are so scarce in our society.

José Vasconcelos (*5*) was right in 1926, and still is, when he argued so eloquently:

> All who compare our Spanish-American and even Spanish culture with the intense culture of the Anglo-Saxon countries will have become aware of the dearth of books among us: not so much because they are expensive, but because it usually is difficult to find them, among other reasons because translations into our language do not exist. Thus, in order to carry our real culture work among our people, it is necessary to begin by creating books, by writing them, by editing them, by translating them. A man who only knows English or who only knows French, can find out about all of human culture; but if he only knows Spanish, he cannot be considered cultured and certainly not informed about world literature and thought. It will always be an embarrassment for us to have to learn foreign languages, not only to communicate with our peers, which is good, but in order to become acquainted with ideas from the rest of the world.
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> If governments of our mestizo nations had the slightest idea of their duties towards their people, if the men in positions of authority could see a foot beyond their despicable self-interest and short-term concerns, if their patriotism were truly a feeling of respect and fraternal love, then years ago our republics would have agreed to establish an enormous publishing house that would give the 90 million Spanish speakers all the books that are lacking, written in their languages and sold at a minimal price.

In view of this tremendous deficiency, the council, during the last 6 years, has published 55 new titles and 33 second editions. We have also published four journals, of which *Ciencia y Desarrollo*, a bimonthly, has a circulation of 70,000; and *Información Científica y Tecnológica*, published fortnightly, has a circulation of 45,000. *Comunidad CONACYT*, with a circulation of 20,000, has been awarded a prize by the Mexican Journalists Club; and *R & D Mexico*, a magazine in English for circulation abroad, particularly in Third World nations, has monthly editions of 80,000 copies. We have published the classics of modern science in complete, inexpensive editions: Darwin, Newton, Fermi, Einstein, Freud, Koestler, Wiener, Poincaré, and others, as well as works by Mexican scientists. These books are sold in 11 CONACYT bookstores set up during the last 4 years, in other bookstores, and in supermarkets in Mexico and throughout the Spanish-speaking world.

CONACYT has helped propagate scientific awareness through other media as well: newspapers, magazines, television, radio, meetings, symposia, and courses on scientific journalism. We have given awards, knowing that these will help create a favorable climate for the development of science and technology, especially among the young. And we have tried to familiarize the general public with the names and faces of members of the local scientific community as well as those of the most outstanding international scientists.

Scientific Development Center in Ensenada

The formation of a scientific development complex in Ensenada, Baja California, is an example of how the pluralistic, multidisciplinary decision-making system that I referred to above works. This complex is composed of the Center for Scientific Research and Higher Education (CICESE), the UNAM Institute of Astronomy, and the Solid State Physics Laboratory of the UNAM Physics Institute (IFUNAM).

In 1972, CONACYT, backed by UNAM, sent a committee of scientists to Baja California to investigate the possibilities of establishing a new scientific institute. With a view of future collaboration, the committee also visited the Scripps Institute of Oceanography at La Jolla, California, near the Mexican border.

In 1973, CICESE was founded as a semiautonomous federal agency with its own budget and organization. Its objectives are to carry out basic and applied research and offer graduate courses. There is also a computer center. At present, CICESE offers masters degrees in oceanography, physics, marine ecology, exploratory geophysics, seismology, electronic optics, and telecommunications. It has 72 researchers and 91 students, nearly all (95 percent) on CONACYT scholarships. CICESE has collaborated with the Electrical Research Institute and the Federal Electricity Commission in the geophysical fields, and with the Office of Telecommunications in the development of rural telephony.

In 1971, the UNAM Institute of Astronomy began the construction of the San Pedro Mártir National Observatory, and the first domes and the 84- and 150-centimeter telescopes were installed. In 1976, work was begun on what now houses the 2-meter telescopes. In 1978, CONACYT arranged for CICESE to cede part of its land to the Institute of Astronomy for new installations; a library, computer center, and other scientific instruments would be shared. With funds from the National Autonomous University of Mexico, the state government, and CONACYT, a piece of adjacent land was bought for a center for research in solid-state physics, which is under construction. The UNAM Engineering Institute also plans to build a laboratory nearby. These programs have been carried out with the cooperation of the University of Baja California, which has on its teaching staff several scientists who work in the centers.

Research Centers for Metalworking

In recent years, many new companies, particularly metalworking firms, have started up in the industrial corridor formed by the cities of Querétaro, San Luis Potosí, and Saltillo. To take care of the technological needs of these industries, CONACYT, with the participation of state governments, private companies, and other governmental and research agencies, promoted the establishment of several research centers: the Mexican Institute of Iron and Steel Research in Saltillo, Coahuila; the Institute of Metalworking Research in San Luis

Potosí; the State Research and Technical Assistance Center in Querétaro; and the Unit for Research on Non-Ferrous Metallurgy of the Center of Research and Advanced Studies of the National Polytechnical Institute (IPN's CINESTAV), also in Saltillo.

These four centers have separate installations and facilities and together employ about 250 people who work in such strategic areas as iron- and steelmaking, machinery and equipment design, forging, thermal processes, machining metal parts, smelting, and nonferrous metallurgy. In 1981, these centers processed more than 700 requests for technical information from the industrial sector, provided 1500 analysis and quality-control services, offered 25 technical training courses to about 500 students, gave 75 technical consultations, and completed about 25 research projects.

Oceanographic Ships

The events that culminated in the acquisition of two ships for oceanographic research offer a third example of a collaborative joint venture.

In January 1979, when Guillermo Soberón was rector of UNAM, the possibility of upgrading the UNAM Center of Marine Sciences and Limnology to an Institute and of purchasing an oceanographic ship were discussed for the first time. The center had conducted research mostly in coastal waters. An oceanographic ship would allow multidisciplinary research in the open sea as well as the training of researchers.

UNAM proposed that CONACYT, the Mexican Petroleum Organization (PEMEX), and the Mexican Petroleum Institute (IMP) together purchase a research ship from Norway at a cost of about 150 million pesos. This ship was launched in September 1980, delivered in November, and registered in December in Cozumel, Quintana Roo. Called *El Puma*, it has room for 20 scientists and 15 crewmen to carry out a long-range program of systematic exploration in Mexican territorial waters on the Atlantic Coast. The need for a second ship for the Pacific Coast was clear—to avoid the time-consuming process of crossing through the Panama canal. UNAM, CONACYT, PEMEX, and IMP decided to purchase one with the same characteristics and to share the operational costs and use of both. An interinstitutional committee was appointed to carry out the programming and to organize the necessary maintenance activities.

CONACYT has informed all of the country's marine research institutions that they can use both ships. Representatives of these institutions met in Mazatlán in May 1982 to discuss the technical possibilities of the ships, and a committee of scientists was convened to evaluate the applications for the use of the ships. The first interinstitutional exercise took place in June 1982.

Concluding Remarks

During the 6 years that I served as director general of CONACYT, we were able to channel an increasingly large volume of resources to the country's science and technology system. This support has been aimed at achieving four basic goals: the establishment of decentralized decision-making in which the scientific community, the government, and the private sector fully participate; the rapid growth of research personnel, which will have medium- and long-term effects on the science and technology system; the creation of a scientific culture so that the country's scientific and technological development is not just economically relevant but politically and socially valuable as well; and the support of technological development in areas considered as priorities in the Overall Development Plan, with the subsequent redefinition of a science and technology system that has grown without guidance and is excessively concentrated in some areas of the basic sciences.

Finally, I should point out that today the country is faced with a serious economic crisis that has decreased the availability of funds for scientific and technological activities in general, including those of CONACYT. During 1982, we have had to decrease the size of the editions of our journals, suspend granting new scholarships, and stop financing new research, infrastructure projects, and important international cooperation programs. The decision has been difficult since we are fully aware that it will have long-term repercussions on the development of a scientific effort that was growing and creating gratifying perspectives. We will try to maintain a solid training program, probably with more emphasis on training within the country, and we will do all that is possible to help provide an adequate infrastructure for the new researchers that we have trained. Finally, we must see to it that Mexico continues to allocate an increasing proportion of its resources—whatever the total sum may be—to science and technology, because a healthy, viable national development project should not let that which is urgent take precedence over that which is important.

References and Notes

1. The law establishing the council as a semiautonomous government institution was issued 29 December 1970 and published in the *Diario Oficial de la Federación*. Today CONACYT's general director is scientific adviser to the President of the Republic, assisting him in defining, executing, and evaluating national science and technology policy. CONACYT maintains a national scholarship program, supports scientific and technological research, promotes the establishment of new research institutions, and promotes and publishes scientific information. Together with the Department of State, it is a cosignatory of international cooperation agreements.
2. W. A. Lewis, *Development Planning: The Essentials of Economic Policy* (Allen & Unwin, London, 1966), p. 25.
3. E. F. Schumacher, *Small Is Beautiful: Economics as If People Mattered* (Blond & Briggs, London, 1973).
4. I. Newton, "Optica o tratado de las reflexiones, refracciones, inflexiones y colores de la luz" (Ediciones Alfaguara, S.A., Madrid, 1977).
5. J. Vasconcelos, "A Guisa de prólogo," *Lecturas Clásicas para Niños* (Secretaría de Educación Pública, Mexico, edición facsimilar, 1979), vol. 1, p. IX.