Brazil Chemistry Program: An International Experiment in Science Education (1979)

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The Brazil Chemistry Program

An International Experiment in Science Education

Board on Science and Technology for International Development
Commission on International Relations
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This report has been prepared by an ad hoc advisory panel of the Board on Science and Technology for International Development, Commission on International Relations, National Research Council, as an assessment of a project supported by United States and Brazilian donors listed on page 5. Funds for the assessment were provided by the Alfred P. Sloan Foundation; Atlantic Richfield Foundation; Office of Science and Technology, Bureau for Development Support, Agency for International Development; and the Brazilian National Research Council (CNPq).

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 Council 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.

PREFACE

Over a span of seven years, two scientific organizations -- one in Brazil and one in the United States -- joined forces to conduct an experiment in postgraduate research and teaching in chemistry. The experiment involved substantial costs, scores of scientists and students, and a unique mechanism for international collaboration in science education.

The results of the experiment need to be assessed and the lessons learned need to be noted. Besides their own needs for analysis of the program, the institutions that were involved frequently receive inquiries from other countries about the usefulness of the model on which the experiment was based, and its possible applicability elsewhere.

In December 1978, therefore, a small assessment team from the United States visited Brazil to discuss the experiment with colleagues there, two years after the official close of the program. The members of the U.S. team were: Dr. Aron Kuppermann, California Institute of Technology; Dr. Henry Taube, Stanford University; Dr. Ernest Wenkert, Rice University; and Dr. Victor Rabinowitch and Mr. John Hurley, National Academy of Sciences. This report is the result of that visit, plus interviews and correspondence with many other participants in the program.

Earlier detailed reports on the Brazil Chemistry Program are available, especially the final report of the two-country supervisory panel. That report provides full details on the various projects in the program and on the Brazilian and U.S. participants. The following pages, however, will not only describe and highlight the program for those unfamiliar with it, but will also attempt to view it in a perspective that becomes possible only with the passage of time.

Special acknowledgement should be made of the help and cooperation of the CNPq and the Brazilian participants in the program, in making the assessment possible. The conclusions expressed in this report, however, are those of the U.S. assessment team.

INTRODUCTION

In the late 1960s, the National Research Council of Brazil (CNPq) and the U.S. National Academy of Sciences (NAS), began a dialogue on the possible contribution of science and technology to the economic and social development of Brazil. At a 1968 joint workshop on this topic, it was established that the chemical-based industries were of high priority in Brazilian industrial development plans. Research and training capability in these fields needed to be greatly strengthened, however.

These conclusions led to the formation of a study group of Brazilian and U.S. scientists to explore the feasibility of specific programs to help fill certain specific needs in chemistry in Brazil. The study group decided that a research and training program involving both U.S. and Brazilian scientists would be the best approach.

A collaborative approach was chosen for several reasons.

First, for certain fields of chemistry, Brazil simply lacked trained personnel altogether, or had too few to begin effective training programs for Brazilian students.

Second, experience has been disappointing in a number of developing countries with extensive programs for overseas graduate training of scientists. Often, students are unable to find a satisfactory research atmosphere and working environment in their home country and simply remain abroad. Among those who do return, many find conditions at home inadequate for a significant use of their advanced training and feel powerless to change the situation by themselves.

Third, some developing countries have attempted to implant new programs and skills by inviting visiting

foreign scientists to work in their universities and research institutions. Most active scientists, however, find it difficult and undesirable to be away from their own country and professional activities for extended lengths of time; consequently, this approach tends to eliminate participation by the most qualified persons.

The Brazil-U.S. collaborative approach, originally proposed by American chemist Carl Djerassi, was designed to overcome the kinds of difficulties just described. It was built on the basic premise that a successful program must aim at the implantation of areas of chemical graduate education and research at sufficiently high levels to produce scientists whose professional qualifications could match those in advanced countries.

The major program objectives outlined by the joint study group were: (a) the development of a Brazilian research capability in certain key fields of chemistry; and (b) the stimulation of long-term cooperative research collaboration in chemistry between Brazilian and American scientists. A mechanism to achieve these objectives would be to encourage young U.S. scientists to become involved in scientific work in Brazil, and to receive adequate academic recognition in the United States for such involvement.

THE EXPERIMENTAL MODEL

The Brazil Chemistry Program was begun in October 1969 and ended -- as a joint program -- in December 1976. The final report of the joint CNPq-NAS panel described the program mechanism as follows:

"Senior Brazilian chemists chose U.S. colleagues with whom they wished to establish a productive cooperative research program based on compatibility of interests and availability of graduate students, instrumentation, and laboratory space. Since it was impossible to attract top-level U.S. senior chemists (who have continuing research programs with large groups of junior colleagues and students at their home institutions) to move to Brazil for long periods, young American Ph.D. chemists (usually from the laboratory of the senior U.S. professor), were selected by the U.S. and Brazilian scientists for assignment to Brazilian universities for two to three years. Their positions in Brazil were equivalent to those of assistant professors in the United States; they conducted specific research projects with Brazilian graduate students and taught courses in their research area. The senior U.S. professors participated in each project through semi-annual visits to Brazil and through continuing communication with their Brazilian counterparts and with the young Americans for whom they were also responsible.

Another aspect of the program was the emphasis placed on training Brazilian doctoral candidates in Brazil, rather than abroad. The reason for this was twofold: 1) in order to train first-class Ph.D.s, the Brazilian institutions needed to modernize their laboratories and equipment; and 2) these upgraded facilities would be conducive to keeping trained Brazilians in Brazil by offering them good research facilities.

The program was truly cooperative. The collaboration included both professors and institutions. The CNPq committed itself to provide fellowships to Brazilian students, purchase necessary equipment and supplies, modernize

laboratory facilities, hire a full-time program coordinator, and find a continuous procedure to expedite importation of small amounts of chemicals not available in Brazil. The NAS accepted the responsibility of finding financial resources to cover the travel of U.S. professors to Brazil for short visits; stipends and travel for the Fellows (American), including a three- to four-week orientation trip approximately six months prior to relocation in Brazil, and scientific meetings in the United States; Portuguese language training in the United States; publication charges for papers written by the NAS Fellows; and salary for a full-time coordinator and secretarial assistance."

The financial and material support for the program came from an interesting variety of governmental and private sponsors. On the Brazilian side, substantial contributions were made by agencies such as the CNPq, Ministry of Education and its Committee for Improvement of University Personnel (CAPES), Federal University of Rio de Janeiro, Brazilian National Development Bank (BND), Fund for Special Studies and Projects (FINEP), and Sao Paulo Foundation for the Support of Science (FAPESP). From the United States side, contributions were made by the National Science Foundation, the Alfred P. Sloan Foundation, the Atlantic-Richfield Foundation, the Andersson Foundation, E.I. duPont de Nemours & Company, Inc., and the Atlantic Petroleum Company of Brazil. The U.S. Agency for International Development in Brazil played a key role in supporting the operating expenses of the program through a contractual agreement with the NAS and CNPq.

Because of the need to base the program in Brazilian institutions with well-established undergraduate chemistry programs, and a nucleus of faculty and facilities able to take on new graduate programs, two universities were chosen — the University of Sao Paulo and the Federal University of Rio de Janeiro. Senior professors at each university committed themselves to providing administrative support and, in some cases, scientific support to elements of the Brazil Chemistry Program.

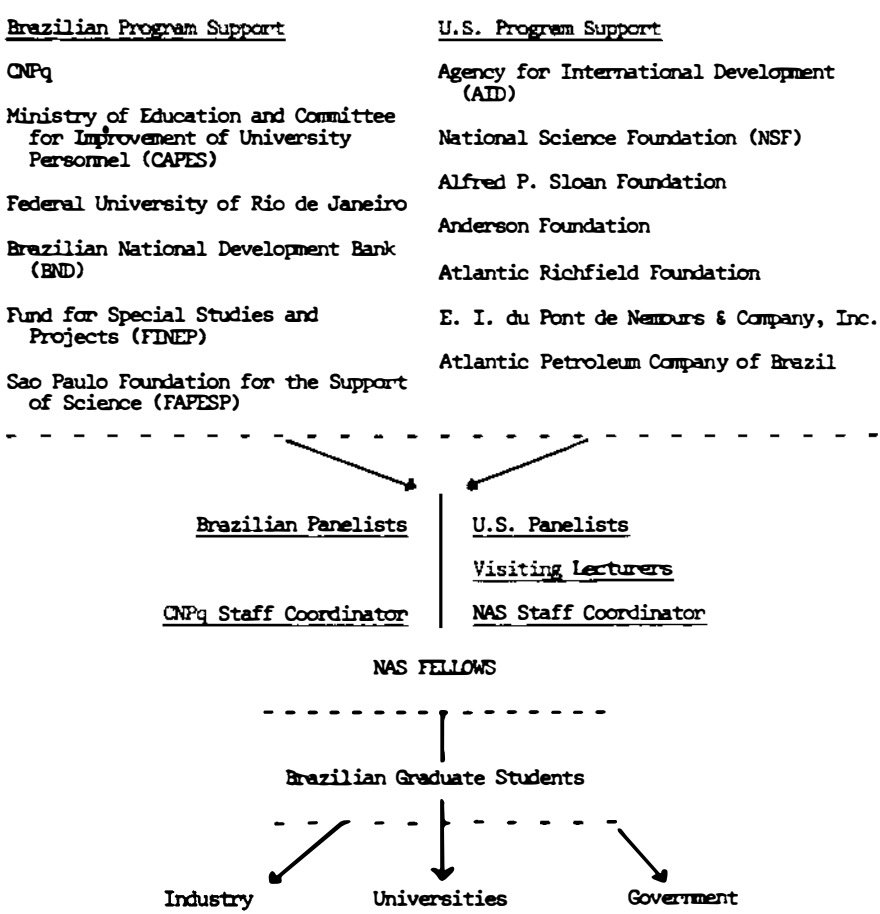
The original program concept aimed for about five new research groups to be set up at the university in Sao Paulo, and five in Rio de Janeiro. After five to ten years, it was expected that the research programs would be self-sustaining and could continue with Brazilian faculty and support alone. It was understood that about seven years would be needed to begin producing Ph.D.s on a regular basis; one or two years would be required to get new laboratories in full operation, and four to five years for the normal cycle of graduate study, research and publication of results.

Thus, the basic program design -- the experimental model -- was laid out as shown in figure 1. Senior Brazilian and American chemists supervised the program and supported it administratively and scientifically. The principal operational support came from a staff coordinator in the NAS and a counterpart in the CNPq. Young American Ph.D.s -- NAS Overseas Research Fellows -- were recruited and placed in the two Brazilian universities for two to three years to establish research and teaching in selected topics of chemistry. Brazilian graduate students were the targets and recipients of the program activities and represented potential new human resources in chemistry for the country. (In some cases, Brazilian students also came to the U.S. for specialized training.) The entire program structure was supported by a combination of Brazilian and American donors, both governmental and private.

The senior American chemists serving as panel members were expected to be active participants in the program. It was planned that they would travel to Brazil several times a year to visit the elements of the program to which they were assigned, advise on research and teaching problems, and give lectures and seminars. (Other visiting lecturers also were incorporated into the program.) Additionally, the American panelists were expected to serve as sponsors or patrons for the NAS Fellows. They would help recruit and select the Fellows, provide working advice and guidance, and also try to be helpful to the Fellows in their search for a U.S. position at the end of their service in the program.

In some instances, senior Brazilian professors visited the U.S. to interview prospective NAS Fellows and help in their selection. The prospective Fellows also made an orientation visit to Brazil before committing themselves to the program.

Figure 1 BRAZIL CHEMISTRY PROGRAM STRUCTURE



PROGRAM INPUTS AND OUTPUTS

In November 1973, an assessment of the Brazil Chemistry Program by Brazilian and American participants led to a decision that satisfactory progress was being made and that another two years would be needed beyond the initial five-year phase in order to fulfill program objectives.

During the seven-year life of the joint program, substantial inputs were made in money, facilities, and equipment, and in the time and effort of participants. It is estimated that an investment equal to about 2.6 million dollars came both from Brazilian sources (about 1.5 million), and from American sources (about 1.1 million). The program participants included 31 Brazilian and American panel members, a program coordinator on each side, 18 visiting lecturers, 17 NAS Fellows, and about 106 Brazilian graduate students.

The seventeen men and women who served as NAS Fellows were a key element of the program. They were the agents for transferring knowledge and techniques related to the target areas of research and teaching. Their ability to transfer their knowledge and experience depended greatly on their capacity to adjust to a different culture, different educational system, and different university pattern of organization and control.

The Fellows received salaries that were based roughly on the equivalent pay for beginning Assistant Professors at U.S. universities. Married Fellows received extra allowances for dependents and school expenses. Certain additional allowances were paid to Fellows for Portuguese language lessons and other expenses, including page costs for publication of papers in scientific journals.

The range of individual service in Brazil for the Fellows was from 15 months to 40 months, with an average stay of 28 months. The Fellows contributed to the program a total of 481 months in Brazil, or just over 40 person years.

Among the sixteen U.S. panelists for the program, the average length of panel service was 5 1/2 years, a figure that indicates good continuity. Because of differing responsibilities and needs within the various projects of the Chemistry Program, the time that U.S. panel members spent in Brazil or on related matters in the U.S. varied considerably. If one assumes that each panel member spent an average of 20 days per year on activities for the program (including correspondence and calls and meetings in the U.S.), then about 300 weeks, or slightly more than six person years were contributed by U.S. panel members, who served without compensation. (Travel and per diem expenses were, of course, provided to panel members when travelling on program business.)

The sixteen Brazilian panel members also made a very substantial contribution of time and energy to the program, but it is impractical to estimate the time involved because so many program related activities were inextricably involved with normal university and departmental efforts.

Active administrative support was given to the program by the Staff Coordiantors in the NAS and CNPq. For about the first two years of the program, the NAS coordinator worked full time on program related matters, and was assigned to the program for 50-75 percent of his time during the remaining years. He was helped by a staff assistant. The responsibilities of the coordinator -- who travelled to Brazil regularly -- ranged over the whole spectrum of the program, from fund-raising, to liaison with Brazilian authorities, to personal counseling of NAS Fellows. His role was critical -- the cement that helped hold together the many elements of the program. The CNPq staff coordinator provided valuable administrative support and devoted over half his time to program matters.

The financial costs of the program are difficult to analyze. The $2.6 million contributed from Brazilian and U.S. sources supported the special costs of the Brazil Chemistry Program, including support for the NAS Fellows, travel and daily expenses of U.S. panelists, NAS staff costs, certain items of equipment, and small purchases of imported chemicals and reagents needed for research in the program. Not included in the $2.6 million were major items such as costs of Brazilian faculty salaries, overhead for laboratories, or support for the graduate students (except for a few small stipends).

From the inception of the program in late 1969, joint projects were eventually established at the Federal University of Rio de Janeiro in polymers, photochemistry, x-ray crystallography, and biochemistry, and at the University of Sao Paulo in electron scattering, ion cyclotron resonance, photochemistry, organic and inorganic synthesis, and electro-analytical chemistry.

Examining the seven-year lifetime of the joint program, certain figures give some sense of the results obtained from the projects just described. From September 1969 through October 1976, 76 graduate degrees -- 60 M.Sc. and 16 Ph.D. -- were awarded to students in the program. Over the same period of time, research groups produced a considerable number of papers: 99 papers were published in international journals and 11 in national journals, while 34 papers were presented at international meetings and 175 at national meetings. One research group obtained two patents.

At the time of the assessment visit in late 1978, nine chemistry projects established through the program were still in operation, six at Sao Paulo, and three at Rio de Janeiro. Since the end of the joint program in 1976, 18 M.Sc. and 10 Ph.D. degrees have been awarded in these projects, and numerous papers have been published.

RESULTS OF THE EXPERIMENT: GENERAL OBSERVATIONS

In the introduction to this report, the broad objectives of the program were listed: a) the development of Brazilian research capability in certain fields of chemistry; and b) the stimulation of long-term cooperative research collaboration in chemistry between Brazilian and American scientists. The principal mechanism to achieve these objectives was the involvement of young U.S. scientists in scientific work in Brazil.

An assessment of whether or not the program achieved its main objectives produces an answer that is "yes." but with qualifications. This section gives some of the impressions and observations of the assessment team, and notes a number of the lessons that have emerged from the experience of the program

In reviewing the history of the program, one is struck by the spirit of collaboration and friendship that has prevailed among the institutions and individuals in the two countries concerned. Despite the boldness of the concept and the complexity of its realization, the program was established rather quickly and proceeded without major catastrophes or disagreements on basic principles. For the Brazilian and American participants, the program has been a highly positive experience in international cooperation.

Brazilian research capability was, in fact, developed in most of the target fields of chemistry. Most of the projects have continued since the formal end of the program, and some of the projects are being led by chemists who were graduate students in the Brazil Chemistry Program. The majority of the graduate students who received Ph.D.s have taken university positions; thus their research and teaching will multiply the effect of the original program.

Inherent in the process of introducing new fields of chemistry research in Brazil, was the introduction of new

methods of teaching, learning, and addressing scientific problems. Moreover, the exposure to U.S. panelists and visiting lecturers added a valuable international dimension to the educational experience of Brazilian graduate students and the professional experience of Brazilian faculty, while also providing useful new contacts and insights to the visitors.

In a more tangible vein , most Brazilian participants agree that the program served a valuable purpose in stimulating greater exchange and cooperation among faculty members in the host chemistry departments, including faculty who were not directly involved with the program. This was partly because of the interest created by new lines of research work, partly because of the background and training of NAS Fellows, and partly because of the possibilities for sharing new equipment or learning new techniques. A further practical benefit was that the bilateral nature of the program and the involvement of both distinguished Brazilian and American scientists created a heightened awareness of the needs of chemistry in Brazil and provided a credibility that was useful in generating new levels and sources of research support within Brazil.

Although large numbers were not involved, the program mechanism enabled a group of able young American chemists to become deeply involved in Brazil's scientific work. While the professional experience of the NAS Fellows in Brazil varied considerably, in retrospect they are nearly unanimous in their affirmation of the personal satisfaction and benefit they received from the program. Three of the Fellows stayed in Brazil in university positions after their service in the program was completed.

Certain aspects of the program, however, developed in unexpected directions or represented difficulties that were never satisfactorily resolved. The following paragraphs outline some of the major concerns and problems.

As a general concern, Brazilian chemists feel that the support for chemistry in Brazil has declined somewhat in the last three years, largely as a result of national economic perturbations resulting from increases in the price of imported oil and accompanying inflation.

A number of good technicians in chemistry departments have been lost because university pay is not keeping pace with that in other sectors; as a result, maintenance and repair problems have mounted for equipment and instruments.

A further consequence of declining support for Brazilian chemistry has been difficulty in supporting ongoing exchange between Brazilian and U.S. scientists; the second major objective of the chemistry program, therefore, has not been adequately met. Although chemists on both sides have expressed regret that this has been the case, and have reaffirmed their positive desire to be part of efforts at continuing cooperation, little financial support for this purpose has been forthcoming from either country.

Some of the Brazilian participants feel that the joint program was terminated too abruptly. Special funding, special logistical and equipment support, and access to distinguished foreign scientists ended suddenly, creating certain disruptions in the ongoing projects. A more gradual phaseout might have been helpful.

A few Brazilian participants have also expressed the view that the special conditions of the program may have created an unrealistic environment for the graduate students. They fear that the students may not be well equipped to cope with the realities of shortages of funds, lack of up-to-date equipment, or difficulties in obtaining spare parts or chemicals that face many chemists in local laboratories.

As might be expected in a complex program with various sponsors and participating institutions, a variety of operational and administrative problems arose from time to time. On another level, clear mutual understanding was sometimes lacking concerning the roles of different participants. For example, was the senior U.S. professor primarily a working colleague of his Brazilian counterpart, a research consultant, a recruiter and counselor of Fellows, or a visiting lecturer? Was the overseas Fellow primarily a postdoctoral Fellow, an independent research investigator, or a full faculty member in the Brazilian university? The role of the Brazilian and U.S. staff coordinators in seeking resolution of such matters was indispensable.

A specific problem related to special conditions of the program was the import of chemicals and spare parts needed in the research projects. Brazil's import regulations made it very complicated, time-consuming and frequently impossible to obtain certain items which were unavailable in Brazil but essential for the research. A special administrative and logistical mechanism finally was devised that enabled NAS staff members to order needed supplies and send them to Brazil with minimum delay. This mechanism was used only for the Brazil Chemistry Program, however, and everyone concerned acknowledged that a permanent solution was required for the broader problem of availability and import of essential scientific supplies. Unfortunately, the problem still exists and the Brazilian chemists who were active in the program feel that their present work has been hindered by the delays encountered since the special import mechanism of the program came to an end.

A number of the original planners and organizers of the Brazil Chemistry Program hoped that its impact on the chemical industry might be considerable. The impact seems to have been slight,however. One basic reason is that the relatively little R & D done by local companies tends to be fairly unsophisticated, while the large multinational companies with Brazilian operations do most of their research abroad. Furthermore, job opportunities in the Brazilian chemical industry are not very attractive for chemists with advanced degrees. The companies primarily hire B.Sc. chemists, most of whom eventually gravitate towards operations or administration.

RESULTS OF THE EXPERIMENT: LESSONS LEARNED

In addition to the general observations that were discussed in the preceding paragraphs, a number of specific conclusions can be drawn from the experience of the Chemistry Program. The conclusions offer useful guidelines for establishing future programs that use the same general model.

1. Strong educational institutions should be involved in the host country as the focal points for the program's graduate research and teaching. Good existing graduate programs with strong faculties and adequate research facilities are essential for the successful introduction of new lines of research. A program along the lines of the Brazilian model can accelerate progress or introduce new lines of work, but it cannot be effective in a department that must be built from the ground up.

2. To the extent that programs can be linked to national development needs, support and interest are likely to be stronger. Programs of this type, require significant financial inputs and a degree of extraordinary administrative support and flexibility. Thus, a perception that a program will have certain direct benefits to national development and will not merely represent academic or theoretical interests is important.

3. If programs are to be successful, the host country commitment needs to be long-range. Research efforts, the training of students, and the building of institutional and personal relationships between countries take time. Moreover, ongoing support is needed to ensure that the students trained in special programs are given relevant work opportunities. For example, a number of participants in the Brazil program suggested that it would have been useful if students could have taken a certain amount of basic equipment with them after finishing graduate work in order to continue their research

in their new locations. It would also be helpful if modest starter grants were available to help former graduate students keep their research active.

4. Related to the need for long-range commitment is the importance of a gradual transition at the end of a program. Access to funds, supplies and equipment should not be terminated so abruptly that research work suffers, nor should program participants be made to feel that their work is no longer important or useful.

5. Basic administrative and technical support is essential to the smooth operation of a program, and support needs and services should be carefully considered in advance. The introduction of unfamiliar equipment and lines of research creates special demands for maintenance and repair, spare parts, and chemicals. If these supporting services are unavailable or can be obtained only with delays and difficulties, the attainment of program objectives will be delayed. Similarly, the introduction -- literally -- of foreign bodies into an existing system such as a university will create special administrative demands related to salaries, housing and a wide range of personal and professional matters.

6. Clear understandings should be reached at the onset of a program with regard to the roles of various participants such as the Fellows, the senior panel members from the participating countries, and the program coordinators. The role of the visiting senior professors should be defined, for example, so that their research and teaching experience will be used effectively and they will not simply become "trouble shooters" for the Fellows. The relationship of Fellows to local faculty and graduate students, their status in the university, and their degree of responsibility for research and teaching all need to be carefully defined. Within the larger context of the total program, the objectives and expectations of participating institutions, departments, and individuals need to be considered, and compatible arrangements agreed upon, before projects are initiated.

7. Having a projected time limitation for joint participation was an important concept for the Brazil Chemistry Program. Both for host country and foreign participants, the realization that the time available is

limited and that the projects will ultimately be the full responsibility of local institutions is good discipline.

From the outset, it was clear that full development of new chemistry laboratories and production of Ph.D.s would take seven to ten years. Several participants have suggested that seven years seemed to be a very appropriate initial target for the binational aspect of the program; it was of sufficient length to offer the possibility of sustained effort, yet not so long that a certain sense of urgency was lost. Moreover, it was agreed that a thorough review of the program would take place at the end of five years; had a decision been reached that satisfactory progress was not being made, the program could have been greatly modified or ended.

8. Continuity of effort is of the greatest importance to individual projects in a program; in particular, the orderly succession of Fellows is critical when local institutions have committed themselves to a project. In a few projects in the Brazil program, considerable time elapsed from the termination of one NAS Fellow to the assignment of a replacement, thus causing disruption in the research and the work of graduate students. The need for continuity is also important with respect to senior foreign professors and the local senior professors.

9. If possible, the financial support for a program should include provision for ongoing exchange of visits and information among former program participants and other scientists in the countries concerned. As mentioned earlier, one disappointment in the Brazil program has been the failure to maintain a very lively exchange between Brazilian and U.S. scientists, largely because of a lack of money to support travel. If both countries could provide rather modest annual sums for travel grants, the impact of the program could be greatly extended and multiplied.

10. A useful adjunct to the basic program model may be to provide for certain graduate students who have completed their work to do postdoctoral work abroad, especially in the laboratories of the senior foreign professors. Such an approach will give them an additional enriching educational experience, broaden their exposure to international work in their field, create a two-way linkage

between the overseas institution and their home base, and prepare them to function when they return home in the role once filled by an overseas Fellow, but with the added advantage of intimate knowledge of the local system. Similarly, it would be useful to find the means to enable especially promising graduate students to broaden their horizons by attending international scientific meetings.

11. The fact that the U.S. senior professors were concentrated in a relatively few institutions was beneficial. It was important, of course, that the U.S. participants were drawn from departments of great stature in the field of chemistry. More than this, however, the concentration facilitated communication among the U.S. participants and created a high visibility for the program among their colleagues. This visibility was useful as a means of getting opinions on research problems, obtaining recommendations for potential NAS Fellows, and recruiting visiting lecturers.

12. The role of the Overseas Research Fellows and their performance on the job are critical to the entire program concept. The Fellows must be mature and sensitive in their adjustment to a new culture and work environment. They must have sufficient professional breadth to initiate research and train students. Their selection and placement, therefore, assume large proportions in the overall program effort.

The experience of the Brazil Chemistry Program demonstrated the need for careful selection of Fellows -- to a very great extent, the success of projects was directly correlated to the initiative and adaptability of the individual Fellow. Participants agree that the host country professor who will work with the Fellow should play a large role in selection and orientation, probably through visits to the sending country. The opportunity for serious candidates for the Fellowship to visit Brazil in advance was a further selection mechanism that is viewed as of the greatest importance.

It is extremely useful if the Overseas Fellow has been associated with the laboratory of the sponsoring senior foreign professor. Brazilian participants further

agreed that practical experience in starting research projects is a great advantage to the Fellows; without this experience, too much time may be wasted by false starts or failure to foresee difficulties.

13. The professional standing and job opportunities for Overseas Research Fellows upon returning to their own country are matters that deserve special attention. Some Fellows in the Brazil program felt that their work was little known or understood in U.S. institutions other than those connected with the program. As a result, a substantial percentage of returning Fellows experienced considerable difficulty in obtaining a suitable permanent job; this problem was overcome in some cases only by extraordinary efforts by the senior U.S. professors. Continuing efforts in providing information about the program might help alleviate this problem to some extent while also helping in the recruitment of new Fellows. It seems clear, however, that special steps are needed in such a program to link prospective employers with the Fellows well in advance of the close of their Fellowships.

14. The roles of senior host country professors, senior foreign professors, and the program coordinators in each country are vital.

The stature of senior host country professors is crucial in attracting good graduate students to a project and in enlisting the cooperation of other faculty members. The stature of the senior foreign professors also is of great importance for several reasons: association with them can be an important aid in the recruitment of Fellows; their involvement can assist in the raising of funds and in attracting support and cooperation from institutions and from other scientists; and their advice can be an important element in improving the substance of the research efforts carried out through the program.

The role of program coordinator in each country requires a person of tact, determination, and the ability to keep the broad program concept in view, despite the distractions of individual project demands. Because of the many institutions and individuals involved in a program supported by different budgets and representing

a range of interests that are sometimes in competition, it is necessary for one person on each side -- the program coordinator -- to follow the various situations closely, anticipate and resolve problems, reinforce achievements, keep all concerned parties informed of the program's status, and try to meld diverse interests into a common purpose.

15. The program coordination in the host country should be centered in an institution that can maintain a good overview of the various projects and provide effective centralized support. In Brazil, the CNPq played this role and experience demonstrated the critical importance of such continuity and the support it provided within the government.

16. A final lesson to be noted is the need to view the program model as a guideline, but not as a boundary that cannot be crossed. Sufficient flexibility should be encouraged to take advantage of opportunities that seem useful and sensible, even though they may represent departures from the model. In the Brazil program, for example, one or two situations arose in which highly capable young faculty members of Brazilian universities had received training abroad in research lines relevant to the program and thus they performed the same function as the NAS Fellows in other situations.

CONCLUSION

In summary, the Brazil Chemistry Program was an experiment that provided a great deal of useful information. The model used was shown to be workable; new research lines in chemistry were implanted, substantial numbers of graduate students were trained, papers of international quality were published, and the research and teaching work in most of the projects continues.

Most participants in the Brazil Program agree that it is beneficial to train graduate students in Brazil. Many also feel that a useful complement to the program concept would be to send Brazilians abroad for post-doctoral work. All agree that continuity of institutions and individual participants is important to the program, and that the model used will only be effective in host country universities that have existing departmental strengths in faculty and in facilities such as laboratories, basic equipment, library, and technical services.

Experience proved that more attention needs to be given to the concluding stages of such a program. Technical support and supplies still must be easily available for ongoing research projects. Starter grants or other mechanisms should be provided so that the products of the program -- its graduates -- can transfer their work to new locations. Overseas Research Fellows need special help in locating new positions when they return home. Provision should be made for travel grants and other devices after the program is finished to make possible ongoing scientific collaboration among scientists of the participating countries.

Without extensive analysis, the costs of the program are difficult to weigh in comparison with alternative models such as sending Brazilian students abroad for graduate work. During the seven years of the program, direct costs totaled about $24,500 per graduate student trained. These costs did not reflect most of the faculty

and other educational costs of the participating university and chemistry departments. When one considers, however, that the cost per student of the Brazil Chemistry Program provided certain benefits to the entire department such as equipment, visiting senior professors and lecturers, and capability in new areas of research, then the cost does not seem excessive.

It should be noted that the model used in Brazil does not necessarily apply only to a Western country - Third World country relationship. Developing countries with strong capability in a particular discipline might usefully form a linkage with another developing country that happens to have relatively less strength in the chosen field. The so-called "middle tier" developing countries might help poorer countries begin graduate teaching and basic research in certain topics. These kinds of relationships would be very much in the spirit of the recommendations of the 1978 U.S. Conference on Technical Cooperation among Developing Countries (TCDC).

The Brazil Chemistry Program is a model that does seem applicable for use in other countries and other disciplines. Careful planning should be done, however, for adaptations appropriate to the particular situations of the participating countries. The lessons learned in the Brazil program and summarized in this report should be useful in the adaptive process.

The National Academy of Sciences is glad to provide more detailed information about the Brazil Chemistry Program or to answer specific questions. Inquiries should be sent to:

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The participants in the Brazil program hope that the experiment will be useful to other countries and institutions, and that it may stimulate interest in new experiments in international scientific and technological cooperation.