The Challenges for Science. Education for the Twenty-First Century
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SCIENCE EDUCATION IN BRAZIL: TOWARDS A NEW PROPOSAL

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Introduction

For the last two and a half years, a major wave of reform has swept the planning of science and technology (S&T) activities in Brazil, especially after the creation of the so-called Sectorial Funds. Associated to the opening of the Brazilian economy, mechanisms were established to assure that a small percentage of the revenues derived from some of those newly deregulated economic sectors should be dedicated to form S&T Sectorial Funds, each one related to a specific economic sector. (Among other measures, the free-market initiatives included the privatization of traditionally government-owned companies in the mineral, telecommunications and electrical segments, as well as the end of the state monopoly in the petroleum exploitation; the key idea was to approve laws that estipulate that a certain amount of the subsequent financial revenues of the newly created enterprises must be invested in scientific and technological programs).

As a consequence, for the first time the financing of basic science and the federal support of research and development projects in Brazil would not depend on yearly negotiations at the Congress and on eventual budgetary constraints of the public administration. (Contrary to the monotonically crescent pattern seen in the most developed nations, in Brazil the total federal expenditure in the broad area of S&T has a 'saw-tooth' profile when considered along the last two decades, since the few spasms of good-will were immediately followed by a return to almost the same levels of insufficient investments). Now, the amount of money to be collected will be mainly subject to the health of the Brazilian economy as a whole and, once allo-

cated, it will be freed from yearly budgetary restrictions. Preliminary estimates are that when the entire set of fourteen expected sectorial funds enter in regular operation in 2002, over one billion reais will be added to the national S&T effort every year, more than doubling the current overall budget for the area. Such funds will have the additional advantage of representing money ear-marked to the end activities.

The promise of financial stability implicit in these new mechanisms has afforded the possibility of long term planning in Brazilian S&T. At first, some of the principal challenges to be faced were readily identified, such as a lack of competitiveness of the technologically based enterprises and an excessive geographical concentration of the S&T activities. Also, a high price had been paid for the decades of progressive strangling of financial resources to the basic sciences and academic activities, reflected by the dismantling of research groups, a fairly recent deviation from the traditional trend of Brazilian scientists remaining to work – even under adverse conditions – in the Country (as well as from the custom of the trained-abroad young generations to return home), and a general lack of confidence by the scientific and technological communities that this bleak picture could be changed in the short term.

A dramatic change in this landscape has been reached in these two and a half years. New programs were devised, the financing of basic science has been reinitiated, and the idea of launching immediate actions within a long-term view of strategic priorities became more pervasive. An opportunity to review those efforts, to correct identified distortions and to incorporate new challenges to the scope of priorities was effective during the process that led to a recent National Conference in Science, Technology and Innovation (CNCTI). At that moment, more than 1,200 professionals of the S&T community-at-large, key businessmen and high-ranked politicians spent three days in Brasília discussing the Brazilian Green Book of science, technology and innovation.[1]

During the Conference, among other relevant issues, several ideas of improving science education in Brazil were discussed, and alternatives for a far-reaching national program in the area were considered. In this communication, I will present a preliminary sketch of one of these possible programs now under consideration by CNPq, the largest Brazilian funding agency for science and technology.

[1] The Brazilian Green Book on Science, Technology and Innovation (in Portuguese) can be downloaded from www.mct.gov.br.

Science Education in Brazil

No new initiative in science education in Brazil could be successful if not based in a careful examination of the large amount of previous experiences in the area accumulated along the last fifty years. In fact, it is very rich the panel of different efforts, programs, and institutions dedicated to this general theme that were initiated in the Country. Museums of Science, experimental parks ("espaços-ciência") for the popularization of science, projects devoted to the production and mass distribution of pedagogical kits, and regional centers dedicated to science education are just some of the few examples of those initiatives that can deserve special analysis for having attained different levels of success.

However, under the present view none of these previous efforts (several of which very successful at their own time) could actually be considered a national program. Not only because in general terms they lacked an organic and integrated national coverage in their scope, but especially due to their inherent liability derived from the unstable guarantee of long-term financing, a characteristic of the entire S&T sector until recently.

The leitmotiv of the CNCTI could be understood as how to incorporate the access to science and technology benefits as a birth right of the 21st Century Brazilian citizens. Embedded in the contradictions of a complex society, with a mosaic of contemporary, modern and centenary needs, the social agenda of Brazil for this century must comprise a basket of priorities, where items typical of the 19th Century citizenry claims still need to be considered a par of contemporary requests. The average citizen nowadays face science and technology choices not only in the great ethical debates, such as those biotechnology and procreation issues, but also more homely in the origin of the food he or she buys, the quality of life in the cities where he/she lives, and (increasingly) in the preservation of his/her individual privacy rights.

This view helps in settling an ongoing debate on the appropriate focus of science education efforts. Should these programs search for the lone 'gold nuggets', i.e. the brightest youngsters with the right aptitude to science and mathematics that must be recruited to assure the quality of the future scientific workforce? Or, instead, should the energies be directed to a more universal coverage of the scientific information, trying to involve even those students that in their incoming professional lives clearly will require scientific information at most as subsidiary?

The technical evolution of the contemporary societies will naturally resolve the above dilemma between those two non-exclusive choices in

favor of the second. To face the challenges of the education for the 21st Century one must begin by the recognition that the literacy indices have ceased to be relevant for the measurement of the aptitude of a society to the modern world.[2] The digital divide, the extension of the alphabetization concept to include the training in information and communication for the average citizen and the internalization of the democratic rights in an increasingly larger number of nations would make scientific education an essential factor of competitiveness in the economic scenario of the present century.

Towards a New Proposal

CNPq has traditionally not only supported individual scientists dedicated to science education but also financed several of the previous programs in the area along the last few decades. As part of these continuing efforts, CNPq has recently issued a call for proposals[3] concerning the production of pedagogical kits, the organization of national Olympiads in science and technology, and the establishment of a cooperative network among the existing science museums and science parks. These initiatives remain essential and must be continued on a yearly basis, as one of the strategic priorities in assuring the lifeline to the basal mechanism of the scientific and technological community. What is needed, and what had its urgency clearly identified in the recent CNCTI, is a national program for science education, an initiative of national coverage in its scope that could take advantage of the continuity of supply of money afforded by the Sectorial Funds.

In the context of major revisions of the planning of S&T, a strategic concept is the idea of establishing a chain of knowledge for each sectorial fund, so that all different scientific and technical aspects, as well as the concerning social, health and legal consequences of that specific economic activity could be thoroughly examined at the highest level of scientific expertise. With the operation of all sectorial funds, the corresponding chains will necessarily intermingle among themselves to generate a vital knowledge network for Brazil. Problems of strategic importance for the Country, and not object of any specific fund, such as the dichotomy preservation/development of the Amazon region – on its beauty and complexity – and the need

[2] A.B. Dias, Parcerias Estratégicas, 11 (2001), 151.
[3] More details can be found in www.cnpq.br.

for a rational exploitation of ocean and coastal resources, can then be included in their multidimensional aspects. By the same token, horizontal actions such as investment in the upgrade of the metrological and electronic instrumentation standards are of interest to several (if not all) sectorial funds, and can be by them financed within the knowledge network idea. Science education, for its long-term strategic impact on the competitiveness of the Nation, is one of those programs that should be prioritized in the new funding scenario in Brazil.

The Centers of Reference in Science

As part of the new approach for the planning of S&T in Brazil, a committee of specialists was invited by the Ministry of Science and Technology with a double mission of first reviewing the performance of the federal institutes of research in their role as strategic agents for the scientific and technological development of the Country and then pointing out new opportunities for their development and of the federal research system as a whole in the next decade. One of the suggestions of these specialists in their report, recently released,[4] was the establishment of an entirely new hierarchy of different institutions that could flourish into a mesh of interconnecting units: the legal existence of coexisting federal institutes, centers of competence, centers of reference, associated laboratories, and so on, will add a welcomed flexibility while increasing the efficacy of the federal system. An important additional recommendation is that a new unit should only be created once its mandate (i.e., the specific directives of purpose and scope of action) and its initial term of operation (number of years to accomplish its objectives before a major review of its current adequacy – that could even recommend the phasing out of the unit – is implemented) were clearly established.

Based on these general guidelines and in response to the universal diagnostic that an urgent action in science education is needed, CNPq has recently invited a team of experts to examine the opportunity of proposing the creation of a national network of Centers of Reference in Science Education (CREC's). While still on the preliminary stages of its work, that panel has already identified a few points that could serve as cornerstones of a new national program in science education, robust enough to grow and adapt itself to an environment of progressive complexity. A program of this

[4] Relatório da Comissão de Avaliação dos Institutos de Pesquisa, available for download from www.mct.gov.br.

kind must initially face the two not always convergent challenges of attending the increasingly sophisticated S&T based demands of a contemporary society, while not excluding itself of a solid national strategy of social inclusion of ever-growing fractions of the Brazilian population into the modern aspects of the 21st Century.

New technologies of information and communication, such as fast Internet links and those in support of distance learning, should be made available for this effort. In fact, in recent years Brazil has made striking progresses in providing Internet access to educational and research applications by the scientific community (which is concentrated mainly in the public universities and research institutes), through the physical backbone of the National Network of Research (RNP). Even so, the dreams of a national coverage of science education initiative by a point-to-point presence in the elementary (or even secondary) schools must face the crude reality that a large number of these institutions do not have the necessary infrastructure[5] of regular libraries, computer and/or science laboratories, or even Internet access (See Tables 1-4).

One should note, however, that concerning the latter issue it should be possible to take advantage of the recently created FUST, the Fund for Universal Access of Telecommunication Services: although not a 'sectorial fund' per se, this fund collects its money from a percentage of the revenues of all telecommunication companies and has the mission of significantly increase access of Brazilians to modern telecommunications tools, including the world wide web. Hence, FUST can offer the required financing for the connectivity of all public schools and libraries in the next few years.

A last hurdle to be passed constitutes a major hindrance to the success of a national science education program designed to reach universal coverage: the weakest link of any program of this kind resides in the lack of adequate training of the average science teacher. Also, once initiated on their professional lives they have few chances of a continuous updating of modern information, a problem compounded by the low wages offered[6] (see Table 5) and the reducing social respect for the teaching activity.

A coherent degree of compromise between efficacy in the near horizon and a national scope of this type of initiative can be reached with the CREC's, whose main role and mandate would consist in the education of the young generation, life-long training of the teaching professionals and

[5] All statistical data concerning the Brazilian educational system are available for downloading from www.inep.gov.br.

[6] Cfr. www.inep.gov.br.

the replication of successful initiatives. Through a cascade-effect, the multiplication of examples will in the end reach over the entire school system. For tactical reasons, at least in the first few years such program should be focused at the students and teachers of the 5th through 8th degrees. Each Center would be established in partnership with the state and local governments in medium size cities of recognized regional influence. A special team of professionals will staff in full time those Centers to provide a space of continuous re-training of science and mathematics teachers of the secondary schools of the neighboring region, and to offer an open-doors environment for the students of these schools. Large band Internet access must be arranged so that those Centers, while possessing a portfolio of activities and specific programs adjusted to the local reality, could actually operate as an integrated national network that will benefit from the support of the most preeminent Brazilian scientists.

Science experiments and computer laboratories that privilege a 'hands-on' attitude and stress the importance of developing a scientific reasoning to deal with the problems of the everyday world should be specially devised. New curricula that break the standards from the traditional isolated disciplinary approach and provide an integrated learning of mathematics and of the basic sciences in their relationship to the environment (both local and in a global scale) and quotidian aspects of life will have to be proposed. The integration of the different CREC's into a single network will make much more efficient the transfer of a locally successful experiment to the entire system.

The pervasive dissemination of pedagogical science kits could be an important part of the program. If a partnership with commercial publishing houses is established, the mass distribution of such kits could be based on an efficient double system in which the support of the Ministry of Science and Technology would assure the coverage of the public system, while a commercial venue space would subsist in the attending of the private sector. The CREC's would fulfill an essential role for the linkage between the two sub-systems, by offering universal training and assistance in the correct use of the kits and also by acting as advanced centers for the experimentation and testing of new concepts and for the development of the most appropriate kits.

A national steering committee will be required to provide the core leadership of the program. Recruiting and training of the full time staff of each Center will depend of how attractive their proposal will be to young professionals. A possible solution would be to establish a special fellowship program that will pay more than the average secondary teacher salary:

recipients will have the fellowships assured for a certain period of time, provided that two conditions are satisfied: first, a minimum performance level – to be established in due time – is to be required to all participants and, second, the selected cadres must assume the commitment to function as 'replicate agents' of the program at the neighboring schools after completing the training period. Besides the normal supply of university trained science teachers, a possible extra source of human power to occupy these positions would come from the early- or middle-carrier changes of professionals trained in the science and technological fields at large.[7] A special training period for all recruited personnel would be required, when identified deficiencies of formation and information could be alleviated.

Conclusion

The urgent need for a national program in science education has been identified. While there is a unanimous claim for immediate action, different and not necessarily convergent strategies for dealing with the problem can be formulated. At CNPq a national program devoted to the creation of centers of reference in science education is being devised, which for tactical reasons will be initially focused at the secondary level public (students and science and math teachers).

The recent creation of the sectorial funds for science and technology has opened a window of opportunity for the design of long-term actions within a strategic perspective for the S&T area. The ancient wisdom expressed by the Chinese proverb "The best time to plant a tree was twenty years ago. But the second best time for doing this is today"[8] translates the feeling of urgency of an immediate action in the subject. A network of integrated centers of reference that have as the baseline directive to transform scientific and technological information into a basic right of the 21st Century citizenship will offer an adequate response to the needs of reducing the regional differences in Brazil while preparing the incoming generations to deal with a progressively complex technology based society. The competitiveness of the Nation in the decades ahead will depend on the existence of a large basis of scientifically and technologically informed citizens.

[7] Some of these ideas have benefited from the proposals presented in the report "Before It's Too Late", The National Commission on Mathematics and Science Teaching for the 21st Century, Washington, 2000.

[8] Ancient Chinese proverb, cited in Ref. 7.

TABLE CAPTIONS

Table 1. Fraction of Brazilian schools at the Fundamental (a) and Secondary (b) levels with Internet access.

	Number of schools	**Internet Access (total)**	**Internet Access (%)**
Total	181.504	12.166	6,7
Rural	111.909	111	0,1
Urban	69.595	12.056	17,3

Table 1a.

	Number of schools	**Internet Access (total)**	**Internet Access (%)**
Total	19.456	6.764	34,8
Rural	679	98	14,4
Urban	18.777	6.666	35,5

Table 1b.

Table 2. Fraction of Brazilian schools at the Fundamental (a) and Secondary (b) levels with library.

	Number of schools	**With Library (total)**	**With Library (%)**
Total	181.504	45.221	24,9
Rural	111.909	4.664	4,2
Urban	69.595	40.557	58,3

Table 2a.

	Number of schools	**With Library (total)**	**With Library (%)**
Total	19.456	16.025	82,4
Rural	679	414	61,0
Urban	18.777	15.611	83,1

Table 2b.

Table 3. Fraction of Brazilian schools at the Fundamental (a) and Secondary (b) levels with computer laboratory.

	Number of schools	**Computer Laboratory (total)**	**Computer Laboratory (%)**
Total	181.504	16.173	8,9
Rural	111.909	306	0,3
Urban	69.595	15.867	22,8

Table 3a.

	Number of schools	**Computer Laboratory (total)**	**Computer Laboratory (%)**
Total	19.456	9.530	49,0
Rural	679	157	23,1
Urban	18.777	9.373	49,9

Table 3b.

Table 4. Fraction of Brazilian schools at the Fundamental (a) and Secondary (b) levels with science laboratory.

	Number of schools	**Science Laboratory (total)**	**Science Laboratory (%)**
Total	181.504	13.202	7,3
Rural	111.909	506	0,5
Urban	69.595	12.696	18,2

Table 4a.

	Number of schools	**Science Laboratory (total)**	**Science Laboratory (%)**
Total	19.456	8.956	46,0
Rural	679	178	26,2
Urban	18.777	8.778	46,7

Table 4b.

Table 5. Average monthly wage (in reais of 1997) of Brazilian teachers working at the 1st-4th grade of the Fundamental level (a), 5st-8th grade of the Fundamental level (b), and Secondary level (c), accordingly to the level of schooling. The salaries at the private system are substantially higher than those paid to public employees. (In 1997, the exchange rate was R$1,00 ≃ US$1.00, while nowadays – 2nd semester of 2001 – is R$2,60 ≃ US$1.00.)

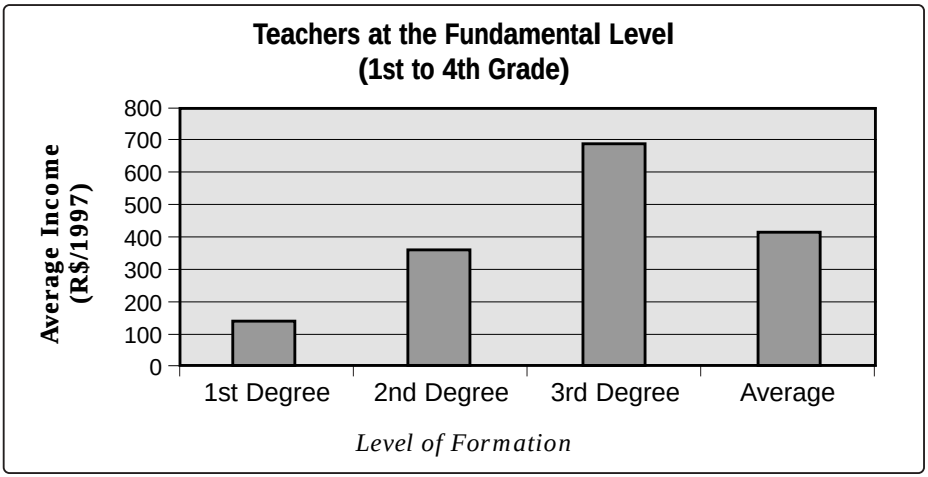

Table 5a.

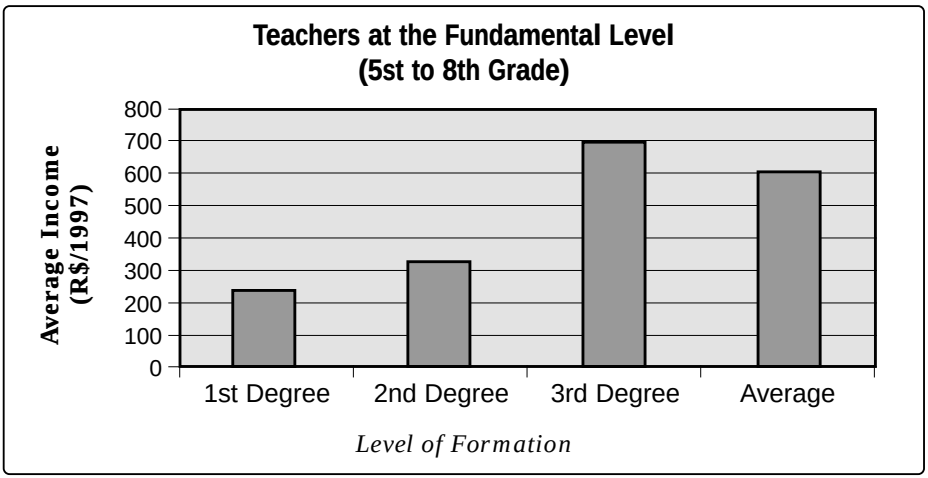

Table 5b.

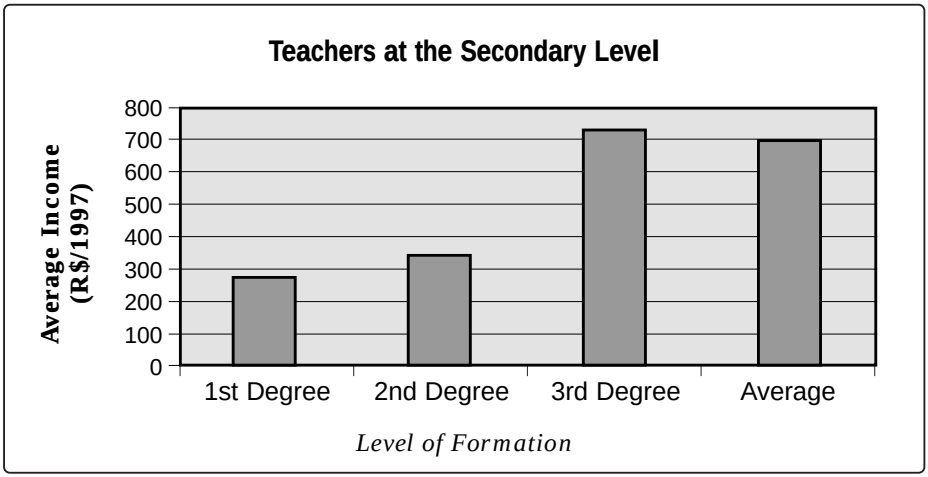
Teachers at the Secondary Level
Average Income (R$/1997)
800
700
600
500
400
300
200
100
0
1st Degree
2nd Degree
3rd Degree
Average
Level of Formation

Table 5c.