

# Scientific and Technological Education in Brazil: Advancements and Challenges for the 21st Century

Claudio André, Norma Teresinha Oliveira Reis, and Demerval Guillarducci Bruzzi

Ministério da Educação, MEC, Brazil

claudio.andre@mec.gov.br, normareis@mec.gov.br,  
demervalbruzzi@mec.gov.br

**Abstract.** There is a complexity of challenges related to scientific and technological education in Brazil, including literacy in basic concepts and principles by students; better pre- and in-service teacher training; sufficient supply of computers, internet and other technological resources to all Brazilian public schools; provision of teacher training on how to effectively use such tools; and promotion of public awareness of science and technology and their vital role socioeconomic development and sovereignty. Recognizing the importance of fostering usage of technologies in education and the urgency of promoting and encouraging synergic efforts in the development, implementation, monitoring and evaluation of policies/programs/projects for science and technology in pre-college education, it was created in 2008, the Coordination of Educational Technologies, in the structure of the Brazilian Ministry of Education. This paper aims to: a) provide a general panorama of Brazilian education; b) discuss some current Brazilian efforts targeted to the advancement of scientific and technological education in pre-college education. As an illustration, we present the so-called “Guide of Educational Technologies,” a publication that allows educational managers to select resources that contribute to the enhancement of education in their school systems. This publication offers a wide range of educational technologies, such as in-service courses for teachers, web resources, software and programs targeted to several educational areas and demands.

**Keywords:** Science education, educational technologies, quality in education.

## 1 Introduction

Education is a fundamental pillar for the construction of a project of society committed to the promotion of sustainable development and social welfare. Any sovereign nation based on principles of democracy, social equality, and ethics is sustained by an inclusive education. For this reason, the Brazilian Ministry of Education has been working towards amplifying access and enhancing quality of education offered in both public and private educational systems. For the Brazilian government, education represents an investment and priority for present and future. It is also a legitimate right of every Brazilian citizen.

In order to better contextualize Brazilian education, we present some aspects of our State. The Brazilian State is a Federative Republic composed of 5.564<sup>1</sup> municipalities, distributed in 26 states and a Federal District and constitutes a legal democratic state, founded on principles of sovereignty, citizenship, dignity of the human person, social values of labor and of free enterprise and political pluralism, according to its Federal Constitution of 1988. A considerable fraction of public policies, such as the educational one is executed in collaborative regime with states, municipalities and the Union. This regime is foreseen in the federative pact, as a constitutional principle.

The Brazilian national territory extends over 8.514.876.599 km<sup>2</sup>,<sup>2</sup> and is divided in five geographical regions that present, despite a linguistic unity, extremely heterogeneous cultural and socioeconomic patterns. As a consequence of differentiated levels of industrialization and socioeconomic development, states and municipalities in different regions present unequal levels of investment and management potential, mainly in societal areas. Such inequalities also lead to disparities in the educational sector, in regard to both economic-financial and qualitative aspects.

The Brazilian educational system is divided in two levels: basic and higher education. The basic level comprises early childhood education (kindergarten and preschool), devoted to children from 0 to 5<sup>3</sup> years old; elementary and middle education, which sum up nine years of compulsory education, from 6 to 14 years old; secondary education, ranging from 15 to 17 years old, which has been integrated to vocational education, preparing youth for the labor market and to continuation of studies. It also comprises modalities such as youth and adult education, devoted to those did not have access or continuation of studies at regular age, and special education, responsible for assisting impaired students, preferably in regular educational systems.<sup>4</sup>

As mentioned previously, public educational policies in Brazil are carried out in an intergovernmental collaborative regime. States, the Federal District and Municipalities are autonomous in the management of their respective education systems. The Ministry of Education, by constitutional principle, exerts normative, re-distributive and supplementary functions, coordinating and proposing educational actions at national level.

The Brazilian educational system is composed of public and private institutions, which follow curricular guidelines elaborated by the National Council of Education (CNE), normative organ associated to the Ministry of Education. In the division of responsibilities regarding the offer of education in the public sector, the Union is responsible for offering higher education. Primary and secondary education should be offered by both state and municipalities. A considerable parcel of secondary education is under the responsibility of states and a certain contingent is managed by federal sphere. Municipalities are responsible for offering early childhood and elementary education with priority.

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<sup>1</sup> Brazilian Institute of Geography and Statistics – IBGE, Brazil in Numbers, v. 14, 2006.

<sup>2</sup> Ibid.

<sup>3</sup> Law number 11.274, February 6, 2006, determines that all six-year-old children be enrolled in fundamental education, which will be nine years long instead of eight, as it used to be.

<sup>4</sup> Impaired students used to attend specific classes/schools. Currently, they are being integrated to regular classes always that possible, as an inclusive action. The purpose is that these students realize they are also capable to learn and interact with the “normal” ones.

The Brazilian Ministry of Education (MEC) has been strengthening partnerships with public and private educational systems (municipal and State levels) and intensifying the dialogue with different societal groups for a collective elaboration, implementation, monitoring and evaluation of policies, programs and projects targeted to strengthen and improve educational services offered.

In an effort to better improve the education offered, the Ministry became concerned with paying closer attention to the need to strengthen scientific and technological education offered in the country. As a response to that the Coordination of Educational Technologies was created in 2008, responsible for conceiving and implementing public policies for the advancement of scientific and technological education in pre-college level, and for integrating and coordinating public, private, and societal efforts to foster education in such fields – so strategic to assure national development, as we will discuss in the coming sections.

## 2 Panorama of Brazilian Education and Public Policies of the Ministry of Education

Brazilian education is guided by a systemic vision<sup>5</sup> [1], that is, the understanding that the success of each educational stage/level contributes to the success of the next. For instance, higher education has to be prioritized if one wants well-prepared teachers. Based on lessons learned from prior public policies that used to prioritize one educational level in detriment to others, and after several societal debates, it has been decided to assure equal priority and financing to all educational levels. The Brazilian Ministry of Education, guided by this *vision*, has been conducting policies aiming to assist and invest equally in all education levels and learning modalities. Actions cover the following areas: a) Basic Education; b) Higher Education; c) Vocational and Technical Education; and d) Literacy and Continuing Education. Programs and projects implemented in each area harmonize and complement themselves and are designed to make it possible for students to have access to all education levels.

In cognizance of the constitutional collaborative regime with educational systems, the Ministry, by means of its Secretariat of Basic Education,<sup>6</sup> has been making efforts to promote social quality in education. This quality has an inclusive dimension, committed to providing an efficacy that could be translated into effective learning, knowledge democratization, and social inclusiveness. Brazil has been gathering substantial progress in the expansion of educational scholar assistance in all levels and modalities<sup>7</sup>. Actually, enrolments enjoyed a quantitative evolution with the inclusion of 97.3%<sup>8</sup> of children from 7 to 14 years old in school. Currently, Brazil is in course of universalizing access also for students in early childhood education and high school, by means of equitable state financing of each phase of basic education.

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<sup>5</sup> Term coined by the current Brazilian minister of education, Dr. Fernando Haddad.

<sup>6</sup> Includes early childhood, primary and secondary education.

<sup>7</sup> Presently, we have two modalities: a) regular education and b) youth and adult education. Thanks to a recent policy, impaired students are being progressively included in regular classes; they used to represent a separate education modality in the past.

<sup>8</sup> Brazilian Institute of Geography and Statistics – IBGE, National Research by Domicile Sample – PNAD, 2005.

Access, though, is far from being the unique challenge. As a matter of fact, results of our *National System of Basic Education Evaluation* – SAEB, reveal that it is mandatory to pay closer attention to education quality – which involves knowledge construction and development of abilities, attitudes and values expected by the end of the school year. Retention, drop out, age-grade distortion demonstrate the urgency of investing and qualifying even more the education offered, as well as of assuring access to all stages and modalities in basic level.

For this purpose, in 2007 the *Brazilian Education Quality Index* – IDEB was launched, in provision of incentives at sub-national level. This index is based on systematic evaluation of how schools are achieving their goals. This indicator is established in a scale ranging from 0 to 10. Using this tool, the Ministry established biannual performance goals for each school and systems until 2022. Currently, IDEB average for elementary level is 4.0 in public schools; while in private institutions the number is similar to industrialized countries, reaching, 6,0. The new index used in its first measurement data from 2005. Two years later, in 2007, it was proved that the joint effort of government and society working for the betterment of education could generate tangible results, as shown in Table 1. Based upon analyses of IDEB numbers, the Ministry offered technical/financial support to municipalities with insufficient indexes. The amount of resources has been defined from adhesion to the so-called *Commitment All for Education* and the elaboration of the *Plan of Articulated Action* (PAR).

**Table 1.** IDEB 2005, 2007 and projections for Brazil

	Elementary school				Secondary School			
	Observed IDEB		Goals		Observed IDEB		Goals	
	2005	2007	2007	2021	2005	2007	2007	2021
<b>Total</b>	3,8	4,2	3,9	6,0	3,4	3,5	3,4	5,2
<b>Public</b>	3,6	4,0	3,6	5,8	3,1	3,2	3,1	4,9
<b>Federal</b>	6,4	6,2	6,4	7,8	5,6	5,7	5,6	7,0
<b>States</b>	3,9	4,3	4,0	6,1	3,0	3,2	3,1	4,9
<b>Municipalities</b>	3,4	4,0	3,5	5,7	2,9	3,2	3,0	4,8
<b>Private</b>	5,9	6,0	6,0	7,5	5,6	5,6	5,6	7,0

In order to enhance this index, the Federal Government proposed, in partnership with society, the so-called *Education Development Plan* – PDE [2], which comprises the Plan of Articulated Actions, and represents an effort involving government, educational systems, private initiative and other societal actors working in partnership to construct basic education with quality and for all. This pathway was chosen because such task is just too large and complex to be achieved individually, hence the entire society should be involved.

The *Plan* sets goals for quality in basic education, contributing for schools and secretariats of education to get organized in assisting students. It also establishes a basis on which families can have support to require education with quality. The *Plan* also foresees accompaniment and advisory to municipalities with low educational indicators. It also comprises investments for qualifying educational managers and

other basic education professionals, evaluation of offered education; consolidation of mechanisms for social engagement in education, such as school councils; as well as actions to strengthen of scientific and technological education.

As a matter of fact, PDE represents advancement in Brazilian public policies for education, in the sense that it works with effective mechanisms of integrating societal efforts to construct collectively the desired education. This *Plan* makes it possible that the Ministry of Education work along with society to construct and consolidate education with quality and inclusive, in the scope of a systemic vision.

### **3 Scientific and Technological Education for Sustainable Development**

Education for the 21st century presents novel and complex challenges for everyone. Teachers and students are faced with demands of living in a societal fabric characterized by globalization, social inequalities, changes in the traditional family structures, diversity, the influence of media – TV, internet, inclusiveness of impaired students, changes in the labor market, just to mention a few. Productive process has been acquiring high complexity, so that quality and permanent learning becomes mandatory [3].

Science and technology sectors are fundamental to sustainable development of nations (Waack and Amoroso, 2005). Since the Industrial Revolution, scientific and technological advancement has been contributing to generate different levels of development amongst nations [4].

In order to assure higher levels of development in science and technology, national governments have been adopting several strategies to maintain and enhance their level of autonomy and competitiveness in these sectors. One such strategy refers to the elevation of citizens' proficiency in science and technology, by strengthening science and technology taught in schools. In fact, scientific and technological education plays an important role in the preparation of citizens considering that society, mainly from the 20th century on, has been permeated by processes, products and services that require of all individuals a certain level of scientific/technological literacy for effective social inclusiveness (Reis *et al*, 2008). Preparation of professionals in such sectors constitutes also a high priority.

Education in science and technology hence plays a vital role in this panorama. Success of the teaching/learning process of science and technology challenges students, educators and policy-makers worldwide. The integrated understanding of sciences as part of everyone's life has not been achieving the expected results. This is partially demonstrated by national and international standardized evaluations applied to students, such as the Programme for International Student Assessment – PISA [5], which shows that many pre-college students worldwide have not been learning these subjects as they were expected to.

Certainly it is also correlated with both global literacy processes starting during or before elementary education, as well as with intra and extra-scholarly factors. As for the intra-scholarly factors, teaching methodologies sometimes go far beyond the typical manner that students learn. Education in science and technology also faces challenges correlated to pre-service and in-service teacher training. Moreover, schools do not always offer proper conditions/technologies to the quality of the development of pedagogical practices in these areas.

Knowledge changes extraordinarily fast these days. Science and technology evolves very rapidly. The internet has been revolutionizing the manner individuals interact with information and knowledge and teachers are not always sufficiently prepared to work with students born into a world much more changeable and dynamic than the world of just a couple of decades ago. Currently, students need to access, filter and organize a wide amount of data coming from several sources. Due to the expansion of technologies of information and communication – TICs, the production and distribution of information became more accessible to a larger amount of individuals. Nevertheless, information should be translated into knowledge. The process by which students used to learn in the near past (the paradigm of Industrial Society), linearly, cannot be used successfully in the knowledge society. Today, students should have abilities to navigate the cyberspace and work effectively with new TICs. This cybernetic environment, by its turn, is characterized by being non-linear and non-sequential [6].

It is necessary that schools evolve as students change their manner of interacting with the fast transformation in the world scenario. The pathway to assure success in this change must take into serious consideration constraints, interests and possibilities of all actors involved: students, teachers, educational managers, community, parents, and so forth, in a collective, democratic process of gradually substituting ancient paradigms, concepts, and methodologies for those required for the school of the 21<sup>st</sup> century.

## **4 Brazilian Policies for Scientific and Technological Education in Basic Level**

Countries that acquired higher levels of socioeconomic development invested in educational programs focused on quality. Evaluation results of education quality have shown discrepancies amongst industrialized and developing countries, and meaningful differences between nations that faced the challenges of scientific and technological sectors and those that did not.

In Brazil, there are several initiatives that contribute to the betterment of scientific and technological education of pre-college students, some of them carried out by government, primarily the Ministry of Education in partnerships with educational systems, the Ministry of Science and Technology, and others by the private sector and other societal actors.

Nonetheless, scholarly education in Brazil should improve its approach in order to adequately meet current demands in this area. Apart from the problems related to initial and continued teacher formation and others intrinsic to curriculum, schools lack the basic structure to scientific teaching and practice. From the 143.631 schools that, in 2005, offered some of the primary school grades: 6% counted with science labs; 12% had computer labs; 15% had internet access; and nearly 23% had libraries. For the secondary schools, the situation is better, but still distant from the ideal conditions to make it possible scientific and technological education with social quality. From the 16.570 schools with secondary education in 2005, nearly 38% counted with science labs; 51% had computer labs; 58% had access to Internet; and 79% counted with libraries or reading rooms [7].

Aiming to change this panorama and enhance the quality of basic education, the Brazilian Ministry of Education is implementing the Program of Incentive and Valorization of Scientific and Technological Education in Basic Level. It is a set of articulated actions targeted to promote enhancement of conditions required to a scientific and technological education with quality and for all.

The program is national and counts with the involvement of public and private institutions devoted to teaching, research, and scientific outreach in all scientific and technological areas. The program includes the following actions/goals: a) incentive to pedagogical innovation programs; b) technical and financial support to educational systems to the enhancement of teaching conditions; c) constitution and consolidation of an evaluation system of scientific and technological education teaching; d) support to actions of initial and continued teacher formation; e) creation and maintenance of an educational portal on the Web; f) support to events and publications, and so forth. Some current actions of the Ministry of Education to the advancement of scientific and technological education include:

*Science Prize:* Financial support to innovative projects of incentive to the scientific and technological education in public schools, as guarantee of sustainability to initiatives that contribute to enhance didactic practices and of integration of school with their respective communities. Targeted to teachers and students of public schools, this initiative focuses on recognizing efforts of educators and students conducting relevant work in science and technology at pre-college level. The prize is not only monetary, but also in form of destination of equipments for schools and various incentives for students.

*Science Olympiad:* The so-called “*Brazilian Olympiad of Science in Public Schools - OBCEP*” intends to engage teachers and students at national level, in actions of teacher formation and students’ research in order to prepare a national competition in science. The initiative is targeted to students, teachers and schools of primary and secondary levels, at state and municipal educational systems. It is similar to the *International Mathematical Olympiad*, and its essence is not purely competition, but cooperation and involvement in an environment of continued learning, in which students participate in exciting activities such as science fairs, science clubs, astronomy clubs, and so forth. The result is a national mobilization that reaches far beyond mere purposes of a competition of “questions and answers”. The purpose is to create a scientific and technological culture among individuals by applying this strategy that has demonstrated effectiveness in different contexts worldwide.

*National Program of Support to Science Fairs:* Conceived to provide financial support to events such as science fairs and expositions, in order to expand and enhance scientific and technological education in basic education. The Ministry of Education encourages educators nationwide to organize science fairs in the scope of their institutions. The concept we adopt here for science fair is a technical-scientific-cultural activity targeted to establish interaction and experiences exchange amongst students and of them with the community they belong to, by the exposition of scientific and cultural productions realized in the educative context. To the community, they are an opportunity to appreciate and understand the phases of construction of the scientific knowledge. For students, events like those contribute to the strengthening of creativity, logical thinking, and research capacity, contributing to build up their intellectual

autonomy. It is recognized that such activities have a positive impact for a meaningful understanding of science and technology beyond the school walls.

*Guide of Educational Technologies*: A tool that education managers nationwide can use to select programs, software, didactic materials, courses for teachers, amongst others, to strengthen basic education. Educational managers use the Guide to select the technologies that best suit their scholarly community's requirements, and make a formal request to the Ministry, which by its turn should assist them with the requested technologies, by means of a process that will be detailed in the coming section.

This set of interconnected and integrated actions also contributes to promote scientific and technological culture. They need to be evaluated in order to identify gaps and to proceed to necessary adjustments. For this purpose, the Ministry evaluates such actions in a regular basis.

There are some other public initiatives of the area of Brazilian technology, carried out by the Secretariat of Distance Learning (SEED), which have been offering valuable contributions to basic education, such as:

*Open University System – UAB* (<http://www.uab.capes.gov.br/>): It prioritizes teacher formation for basic education, by means of wide articulation among Brazilian universities, states and municipalities in order to promote, through distance learning methodologies, access to higher education to populations without access to this level of education.

*Teacher Portal* (<http://portaldoprofessor.mec.gov.br/>): The Ministry aims to include teachers who live outside large urban centers in the environment of technologies. The portal content comprises classroom suggestions in accordance with each subject matter curriculum and resources such as videos, pictures, maps, audios and texts, which contributes to make studies more dynamic and engaging. In this *Portal*, teachers could prepare classes, obtain informed about in-service courses offered in their respective municipalities and in the federal area, and about specific legislation. Chats, blogs and online seminars stimulate communication and interaction among teachers, who will count with digital libraries and museums and be encouraged to create Web sites in schools. Initiatives of educators will be presented in the so-called *Teacher Journal*, with usage of journalistic texts and experimental videos.

#### **4.1 The Guide of Educational Technologies – A Brazilian Innovation for the Enhancement of Quality in Education**

For more than a decade, the Brazilian Ministry of Education has been conducting the largest program of distribution of didactic books in the world. Teachers receive a guide in which they select, in order of preference, books they would like to use in the coming scholar year, for the main scholar subjects. Those books are selected to compose a ministerial guide after a comprehensive evaluation of quality, adequacy, and other criteria such as inclusiveness, absence of prejudice and other parameters.

Similarly, a Guide has been launched for the selection of educational technologies capable of enhancing quality of education. The *Guide of Educational Technologies* is a publication that comprises descriptions of a set of technologies that will enable education managers to select those capable of better contributing to enhance pedagogical practices in their scholarly systems. It contains educational technologies: techniques,

apparatus, tools and other resources with usage potential in the development and support to the accomplishment or enhancement of educational processes.

The Guide is divided in five areas, as follows: a) management of education; b) teaching-learning process; c) preparation of professionals of education; d) inclusive education; and e) educational portals (MEC, 2008). This set of technologies comprises commissions, programs, software, educational activities, projects, systems, techno kits, teacher formation programs, courses, portals, materials for impaired students, and more. Such technologies are targeted to scholarly community from early childhood education until high school.

Aiming to select technologies to compose the Guide, the Ministry published guidelines and requirements that such technologies should present. Based on that, public and private institutions submit their proposals, which are then submitted to ministerial evaluation. Any individual can present a proposal.

A set of technologies is then selected to compose the mentioned Guide – they are pre-qualified. A technical-academic committee is responsible for evaluation of conditions for pre-qualification of the educational technology. It is taken into consideration the expected impact on quality indicators, technical and pedagogical quality, and experience of usage in the pedagogical practice, coherence between objectives and methodology and potential of dissemination. This process aims to:

- Pre-qualify educational technologies as referential of quality, for usage in schools and educational systems;
- Disseminate standards of quality for educational technologies capable or guiding the organization of work of professionals of basic education;
- Encourage specialists, researchers, universities and societal organizations to create educational technologies capable of contributing to elevate the quality of basic education;
- Strengthen a culture of production targeted to quality in the area of basic education and their concrete standards.

The Guide was sent to municipal systems and education managers chose technologies that would suit their educational systems better. Recently, the Ministry made available technologies for correction of the age-grade distortion problem. Three programs, including distribution of material and continued teacher formation, were made available by three distinct private institutes for municipalities presenting such situation in their scholarly public systems.

The Ministry sends a correspondence to each municipality containing a form and a manual with information about the three technologies. After reading the manual, the



**Fig. 1.** Guide of Educational Technologies – cover page

education manager fill in the form, choosing technologies in order of preference, from 1 to 3. This has been made in order to assure that at least one of their preferences would be provided, although the purpose is to provide their very first choice. They send the form back to the Ministry, which proceeds to transfer financial resources to those institutions that will offer the program.

The execution process thus involves decentralization of monetary resources to those private institutes and they are in charge of conducting their programs autonomously with municipalities. They will be accompanied during the process through monitoring and evaluation actions, conducted by universities in partnership with the Ministry of Education. After two years, pre-qualified technologies could be certified by the Ministry, whether after evaluation it is verified a positive impact on the evolution of the quality indicators for education, such as the IDEB, in those municipalities in which they were applied.

As a result, there will be a set of technologies proven to be successful and that could be continuously requested by educational systems in the coming years. New editions of the Guide will be launched annually so that not only the institutions selected previously could present their technologies for evaluation, but also new institutions, so that a wider range of new technologies should be pre-qualified and made available for the scholarly community choice.

## **5 Conclusions, Challenges and Perspectives**

Advancement in scientific and technological fields contributes substantially to promote autonomy, competitiveness and sovereignty of nations. This scenario claims for the strengthening of scientific and technological education in basic level. By means of scientific and technological education it is possible to capture interest of young students towards scientific and technological careers. It requires investment and development of pedagogical strategies capable of turning the scientific and technological language and contents attractive to this audience. It is also necessary to invest in the preparation of teachers and in equipping schools with resources to facilitate scientific and technological literacy, and effective inclusion in current knowledge society.

A set of initiatives could contribute substantially to enhance scientific and technological education offered in schools in the coming years in Brazil. Some of them are: a) the enhancement of initial and in-service teacher formation; b) provision of computers and internet to public schools; c) monitoring, evaluation, and continuation of governmental and non-governmental initiatives targeted to the promotion of scientific and technological education; d) promotion/participation in events to debate the issue with national and international individuals, in order to access how they have been dealing with their own challenges.

It is also necessary to encourage a culture of science and technology among the Brazilian population. The creation of the Coordination of Educational Technology in the Ministry of Education is a giant leap towards achieving the necessary visibility to the effort of strengthening science and technology taught in schools. It is also necessary to invest more in outreach materials, marketing and other strategies to popularize science and technology.

Although there are several actions carried out by different actors to promote scientific and technology education in Brazil, we still need some extra coordination in order to increase their effectiveness. It is necessary to better identify our real population needs situated in individual's territoriality and diversity, and after that, there is the challenge of identifying public and private partners, in order to create synergy of efforts towards pre-established goals. Innovation should also be welcome, such as programs in space education, environmental sciences, and similar subjects that can raise students' interest to learn science and technology in a meaningful, integrated, and fascinating, manner.

In tune with requirements of knowledge society and Brazilian societal demands, the Ministry of Education, in partnership with educational systems, has been working towards constructing scientific and technological education with quality and for all.

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