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Education in Brazil: Access, quality and STEM

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Executive summary

The main educational policies of Brazil focus on increasing the still low levels of formal education of its population. This effort has been focused on all levels of education, and the main challenges are related to access of children, young people and adults to education – independently of the level of education, and quality. There are some strategies to develop STEM education, but these were found mainly at the higher education level.

The analysis shows that access to, and the quality of, education are priorities when compared with more specific policies focusing on STEM. These are main concerns at all levels of education. In terms of access, the major policies are focused on reaching a greater number of potential participants in education. Most of these policies affect not only the great urban areas of Brazil, but also less socially and economically developed states and municipalities, including populations living in far reach areas, such as those populations living in the Amazônia forest. These policies are not only educational in purpose, but have a strong social component, since they are associated with the reduction of poverty and social inequality. The other main concern of the Brazilian authorities – and of many educational scholars as well – is the quality of education. This affects both STEM fields but also the general educational curricula. Part of the problem is related to the poorly trained or lack of training that teachers at all levels of education have, which complemented with unbalanced teacher/student ratios contributes to high rates of drop-outs and retention. As the report shows, some of the policies and initiatives to improve quality are clearly associated with STEM fields, and with fostering the engagement of children in technical oriented education.

STEM policies appear much more clearly as a challenge at the level of higher education. These policies focus on changing engineering education by adopting a problem based learning approach. However, the major program fostering STEM fields in Brazil seems to be a training and mobility program called Science Without Borders, which grants more than 100 thousand scholarships to undergraduate and graduate students, exposing these students and researchers to international environments of high competitiveness, research and teaching quality, and entrepreneurship. Still, the access policies of previous education levels and even at higher education impacted the number of students and graduates that are rising but still far from the STEM figures of other BRIC countries.

The Brazilian education system: an overview and introduction

Since the Brazilian education system is rather complex and dependent upon various policy and administrative levels, the report starts by providing an overview of the education system, including the special education regimes that impact on the education of ethnic groups and disadvantaged groups not only in terms of poverty but also in terms of distance and location.

The education system in Brazil is determined by the Federal Constitution and the National Education Law (*Lei de Diretrizes e Bases da Educação Nacional*). It is managed and organized separately by the various levels of the government and public administration: the federal government, the states, the federal district, and the municipalities. Each of these levels is responsible for the educational sustainability, funding management and resource distribution. The new constitution assigns 25% of the state budget and 18% of federal and municipal taxes to education.
Brazilian education is regulated by the federal government through the Ministry of Education, which defines the orienting principles of the organization of educational programs. The local governments are responsible for the establishment of state educational programs and follow the federal education guidelines using funding provided

by the federal government. Since 2006, mandatory schooling is nine years (it was eight before), having as a key objective keeping the children at school for as long as possible, but above all, to improve the quality of the initial training and literacy.

Still, several scholars in Brazil deem this time as insufficient. Still, education in Brazil is a consigned right for everyone by the Constitution of 1988, which establishes that ‘education is a right for all, a duty of the state and the families, and is to be promoted with the collaboration of society with the objective to develop citizenship and the participation of citizens in the workforce, working towards the social benefits that all can benefit’ (Pereira and Bahia, 2011). Education is clearly understood as a means to guarantee a more equalitarian society in one of the most unequal societies in the world.

The Brazilian education system presents other challenging problems, mainly the need to be re-organized and become more efficient. Brazil’s public spending on education as a percentage of GDP has nearly doubled since 1970 and now hovers around 5 per cent. This rate is actually higher than the Latin American average, which stands at 4 per cent of GDP. In face of these figures, scholars such as Sandoval, point the mismanagement of resources as one of the main problems of the Brazilian education system, and not so much the lack of funding (Duarte, 2005).

Stages of Brazilian education: educational structure

The Brazilian education structure is divided by stages.

Basic education

Basic education is the first level of schooling comprehending three sub-stages: child education (for children aged up to 5 years old), fundamental education (for students aged 6 to 14 years old), and middle education (for students aged 15 to 17 years old). Throughout these sub-stages of basic education, children and teenagers should attain mandatory education, which is perceived by the constitution as a key factor for the exercise of citizenship. Another objective of basic education is to prepare students with the basic education to lead them to move towards higher educational levels, including in higher education.

Despite the strong correlation between standard ages and determined educational levels, attendance at any educational level is independent of age, meaning that students from any age can attend any level of education. In this sense, and taking into account the high illiterate rate of adults in Brazil, it is the role of the state to guarantee by all the means possible that teenagers and adults that have not attended school in the expected ages, can attend school and have learning opportunities (Barros, 2007). The objective is that they attain basic schooling.

According to data from the National Institute of Studies and Research in Education, about 51.5 million students are enroled in basic education, including those students from the technical teaching modalities, special education (for physically and mentally hampered people) and education of teenagers and adults.

Sub-stages of basic education

Child education

Child education focuses on the physical, psychological, intellectual and social of the child. The activities that are performed are a complement to family and social learning.

Children up to 3 years old may attend kindergartens or similar institutions, but children with ages between 4 and 5 years, have their teaching performed in pre-schools. Parents do not need to enrol children aged up to 5 years old, but the state should provide the possibility that these children may go to kindergartens or similar institutions. According to Brazilian laws, the municipalities are responsible for offering child education, which should be public and free, and also for the management of private institutions.

The number of children which attend kindergartens increased considerably in the past years. The School Census of 2010 found an increase of more than 168 thousand children enroled in comparison to 2009, and 79% more in relation to 2002. In 2010, 6,756,698 children are enroled in child education, 71.8% of which in kindergartens and municipal pre-schools (4,853,761), 1.1% in state, less than 0.1% in federal, and 27.1% in private institutions.

Fundamental education

Fundamental education is mandatory, meaning that all children aged 6 to 14 years old should be at school. The state is obliged by law to offer this education as free and universal. The mandatory nature of this education means that this is a minimum educational standard for all the citizens irrespective of their age. This highlights the concern of the Brazilian government with the need for their adult population to go to school to improve its formal qualifications and abilities to learn. Upon the conclusion of this education, the student should be able to read, write and perform calculus. Other objective is to develop the capacity of understanding the natural and social environment, the political system, technology, the arts and the basic values of society and family.
In 2009, 92% of the municipalities had implemented the 9 year fundamental education in according to Law 11.114 which determined fundamental education to last for nine years (the child start schooling when she or he is 6 years old and concludes when she or he is 9 years old, that is the ninth year). According to the School Census of 2010, 31,005,341 students are enroled in the regular fundamental education, the majority (54.6%) in the municipal network, 32.6% in the state schools network, 12.7% in private institutions, and 0.1% in the federal. To assess the literacy of the students, an exam called *Provinha Brasil* was implemented. It allows assessing the skills of students concerning the functional literacy of students, and helps preventing that children get to the last year of fundamental education without being able to read, write or basic numeracy.

It is important to note that there is not a standard universal educational curricula in Brazil, in other words, the curricula varies by state. Instead, the educational curriculum is oriented by curricula guidelines that broadly orient the state and municipal education systems, with the support of MEC, which elaborates curricula references and orientations. According to the educational law (*Lei de Directrizes the Bases*) the Federal state establishes basic curricula guidelines that are complemented by states and municipalities according to the needs and specificities of those regions. The basic curricula guidelines however defines compulsory disciplines among which mathematics and a set of disciplines of the “physic and natural world”, which include general science, physics and chemistry.
In the first cycle of fundamental education, in the discipline of mathematics, the pupils need to learn the meaning of the natural numbers, using them in several situations that include counting, measurements and numerical codes. The pupil should know the meaning of mathematical operations, being aware that a problem can be solved by different operations (e.g. sum, subtraction, multiplication) or that the same mathematical operation can be related to different types of problems. Basic references of space and time should also be learned as well as perceptions of size, temperature, and identify tables and graphs. The second cycle introduces pupils to rational numbers (fractions and decimal numbers), and teaches them to write, read and order natural and rational

numbers. They start to identify the characteristics of geometric figures and represent data in tables and graphs. In the third cycle, the students should interpret problems, plan their resolution, compare and order natural, rational and full numbers, use algebraic representations, understand geometric notions to represent the moving of the Cartesian referential, and identify and construct plain and spatial figures and use measurements correctly. In the fourth and final cycle, the pupil should solve equations; fully understand scales, percentages and simple interest rates. They should read and interpret statistical data and know how to identify simple probabilities.

In the first cycle, in the disciplines of the “physic and natural world” the pupils study the soil, heat, water, light and their relation to the natural environment and life. They identify some characteristics of the human body in the different stages of life and perform basic experiments to understand the properties of materials and power sources. In the second cycle, the pupils should identify causes of pollution; understand the relation between soil, water and living beings as well as the human body functions associated with health and well-being. The pupils should also understand food as a source of energy, nutrition functions and the transformation of food in the digestion process. The students learn to characterize the male and female reproductive organs, the puberty and identify the different manifestations of energy and how one type of energy transforms into another. In the third cycle, it is expected that the pupils describe the food chain and the role of humans in that system. The pupils should also know how to describe the movements of the sun, moon and stars in relation to the horizon and locate cardinal points. They should characterize ecosystems, explain food digestion, the stages of the menstrual cycle, pregnancy, and the relation between the dissemination of sexually infected diseases and the absence of condoms. In the fourth and final cycle, the pupils should be able to compare geocentric and heliocentric theories, understand the creation of Earth and the natural history of the planet, and recognize the relation between the function of nutrients and the reproductive system.

In 2009, a study carried out by the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics), indicated a considerable evolution of the proportion of pupils considered as having learned the minimum requirements in mathematics after concluding the first year of fundamental education. The proportion evolved from 14% in 1999 to 33% in 2009. However, this proportion was 15% for the pupils concluding in the final year of fundamental education changing little from 13% in 1999. Yet, this evolution is related to growing number of hours that students spend per week having mathematics classes in fundamental education (2.7 hours/week) which is now closer to the OECD average of 3.3, and not overly distant from countries such as Australia 3.5 and Japan 3.7.

Middle education

Middle education is the responsibility of the states, and lasts for 3 years. During this period, the knowledge accumulated during fundamental education is deepened. This pre-stage also aims to foster ethical training and guidelines, the development of intellectual autonomy and critical thinking, and the understanding of scientific and technological fundamentals of the productive process. All of this allows the student to conclude basic education with the abilities to choose different life paths, either focused directly on the labor market or towards higher education.

The middle education follows the same structure as the fundamental teaching, but the number of mandatory disciplines varies and can be as high as sixteen[1]. The number of mandatory disciplines has led to many discussions over the importance of some of the mandatory disciplines, with some scholars arguing that such a high number represents a burden to teachers and does not benefit the students that are not entering high education, while others argue that that number of disciplines is absolutely necessary to prepare the Brazilian workforce for the knowledge society. The disciplines of mathematics, knowledge of the physic and natural world and environmental education are part of those mandatory disciplines and are disciplines that gather consensus on remaining mandatory, among scholars and policymakers. A key criticism of the number of disciplines is that they disperse the pupils learning focus away from the essential disciplines of "mathematics, Portuguese language, and sciences"[2]. Still, middle education in general suffers from several problems and one of them is related to the low quality of teaching. According to an assessment exercise of the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics), in 2009, only 50% of the Brazilian youth concludes this educational stage in the expected age (until 19 years old), and of these only 11% learn what is considered as minimum in the discipline of mathematics (it was 12% in 1999). This can be related to the relative number of classes per week in mathematics which is 2 per week, when compared with the OECD average (2.6), Japan (2.3) or Australia (2.7). However, it can also be related to how the teachers organize the classroom. In Brazil 7% to 12% of classroom time is dedicated to non-academic activities, 27% to 31% to the organization of the classroom and only 62% to 66% to effective academic activities. In the OECD, the same percentages are 0%, 15%, and 85% (data from the *Conselho Nacional de Secretários de Educação, Consed*; National Council of Education Secretaries).

In this sub-stage, learning a foreign language is mandatory, and since 2008 the teaching of philosophy and sociology was also made mandatory. The last stage of middle education prepares the candidates for the access exam to the universities. The exam is currently offered by more than 2665 public and private universities, and it is the most important criteria to access higher education. The exam is applied by foundations or commissions especially created for its application.

The schools of professional, scientific and technological education are also part of middle education. There are more than 314 units dedicated to these types of education in all the states of Brazil, comprehending Federal Institutes of Education, Science and Technology, Federal Centers of Technological Education, and Technical Schools associated to Federal Universities and Technological Industrial Universities.

According to the School Census of 2009, a total of 8,337,160 students are enroled in the regular middle education, 85.9% in state institutions, 11.7% in private institutions, 1.3% in municipal institutions and 1.1% in federal schools. The Southeast region has the

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1 See http://siau.edunet.sp.gov.br/ItemLise/arquivos/notas/DELCEE77_08.HTM?Time=1/16/2013%202:31:40%20AM

2 See http://oglobo.globo.com/educacao/educadores-criticam-inclusao-de-etica-cidadania-no-curriculo-6991486

greatest number of enrolments (3,356,293 students), followed by the northeast (2,512,783 students). Center-West has the lesser number of students enroled (607,722 students). In 2009, there were 25,293 institutions providing this type of education in Brazil.

Options of basic education: technical education

The student while in basic education may at the same time benefit from technical and professional courses, which are offered during middle education. Those who already have a middle education diploma can also participate. The student can benefit from technical education through three modalities: integrated (the student has technical education in parallel to middle education), concomitant (the student has technical education in parallel to middle education, but in different educational institutions), and sequential (the student does technical education after holding the middle education). According to the School Census of 2010, 1,140,388 students are enroled in technical education, representing a 74.9% increase in enrolments since 2002.

Since 2008, the federal educational network is organized in 38 Federal Institutes of Education, Science and Technology, resulting from 31 federal centers of technological education (*Cefets*), 75 decentralized units of teaching (*Uneds*), 39 agronomic schools, 7 federal technical schools and 8 associated schools to universities. The Federal Institutes of Education, Science and Technology offer training to teenagers and adults, technical courses, short higher education courses (*bacharelatos*), bachelor, master and doctorate degrees. They are also professional skills accreditation and certification agencies. These institutions, besides qualifying professionals for the various sectors of the Brazilian economy, also perform research and develop new products and services in collaboration with firms and local communities.

Higher education

Higher education in Brazil is offered by universities, university centers, faculties, superior institutes and centers of technological education. Brazil possesses a highly diversified public and private higher education system. It can be classified according to two criteria: academic organization and administrative status.

Academic organizations are divided into universities, university centers and non-university institutions. Universities are required to carry out research, community outreach, teaching etc. University centers are multi-course teaching institutions which do not have to undertake research (that is, they have autonomy to create courses and places). Non-university institutes do not have any autonomy. According to their academic status, the HE institutions may be public (federal, state, municipal) and provide free education, or they can be private (community, denominational/religious, philanthropic and private for-profit) (Neves, 2009).

According to statistical data by the Ministry of Education, there were 2,377 higher education institutions in 2010, of which 2,099 are private and 556 are public. The number of enroled students in higher education increased from 3,036,113 in 2001 to 6,379,299 in 2010, corresponding to 110% growth in the number of enroled per year within this period, and to a system moving rapidly to a massification stage. 74% of the students enroled in higher education were enroled in the private sector. The number of graduates also more than doubled from 2001 to 2010, reaching in the latter year 973,839 tertiary education graduates. The explanation for this growth can be associated to several factors.

From the demand side, it is explained by the recent economic development of Brazil that is increasingly demanding skilled and highly skilled workers. Brazil's economy generated 1.7 million formal jobs in 2009, an increase of 4.5% in relation to the previous year[3]. This demand provides an opportunity for change and to reduce the high inequalities of the Brazilian society. Sandoval (2012) among others stated that due to continuous robust economic growth, the country become an economic powerhouse in both Latin America and the developing world. He also found that despite the recent drive for education inequality levels continue to persist at high levels and that substandard education continues to be a main contributor to this inequality (Gomes, 2012). The driver for education by the Brazilian government, and its education reform though is perceived as representing an effective instrument for further development and a more equalitarian distribution of income. The fact that 53% of the Brazilian households are currently considered to be "middle class", representing a rise of 22% since 2004, is associated with the learning and social benefits of a population more involved in higher education (OECD, 2011).

From the supply side, it is related to an increasing funding of scholarships and subsidies to students (e.g. see programs FIES and PROUNI below), the increased vacancies in the higher education federal network, the opening of new campuses and the creation of new higher education institutions.

The Brazilian government has projects that aim to facilitate access of students and academics to higher education and/or help improve the quality of teaching at federal universities. Some of the major programs are mentioned below:

FIES: This program aims at funding higher education studies of students that have difficulties in supporting the cost of their studies.

PIBID: The institutional program of initiating fellows to teaching offers grants for students with presence in class which perform an internship in public schools, and that, when graduated, guarantee that they will work in the public network of education. The objective is to anticipate the link between future teachers and the classroom. Through this program, there is an articulation between higher education (through learning and training), school, and state and municipal systems.

PROUNI: The program "University for all" was created in 2004 to grant full or partial fellowships to post-graduation students (also specific post-graduations) in private higher education institutions.

REUNI: The program looks to broaden access and retention in higher education. Its goal is to double the number of students in higher education in 10 years, from 2008 onwards and foster the enrolment of 680 thousand students in post-graduation courses.

The candidate/student can opt for three types of graduation: *bacharelato* (short education), *licenciatura* (bachelor), and technological training. The post-graduation are divided between *lato sensu* (specializations and MBAs) and *strictu sensu* (masters and PhDs). Besides the presence, the student should attend at least 75% of the classes and evaluations, and it is still possible to graduate with distance learning. In the latter modality, the student receives books and textbooks, and has internet support, not being required his or her presence in class. Most enroled students (in courses requiring the presence of students in class) are pursuing *bacharelato* degrees (near 4 million students), more than 900 thousand *licenciatura* degrees, and more than 500 thousand technological training degrees.

[3] Data from RAIS – a registry of formal establishments and jobs administered by the Brazilian Ministry of Labor that includes both private and public job creation.

There are also degrees that combine the presence of students in class and distance learning. The enrolment of students in distance learning has been increasing substantially, including in STEM fields (Steil and Barcia, 2006). In 2001, less than 1% of all enroled students were enroled in distance learning, while in 2010, around 15% of all enroled students were enroled in this type of education programs. Most students enroled in distance education are enroled in *licenciatura* degrees (more than 400 thousand), about 300 thousand in *bacharelato* degrees and slightly more than 200 thousand in technological training degrees.

The number of students enroled in technological degrees has been growing rapidly. In 2010, almost 800 thousand students were enroled in this type of degree when this number was barely 70 thousand in 2001. The majority of the students enroled in technology training degrees are in marketing/management and administration courses (44%), while those based on the more technological courses are significantly less: Information Processing Systems (9%), Information and Communication Systems (7%), and Engineering (4%).

However, some analyses of the entire higher education system (such as the one from Chiarini and Vieira, 2012) indicate that the majority of Brazilian students seem to opt for the fields of social sciences and humanities. The reason may lie on the fact that the majority of higher education institutions are private, do not require exams facilitating entry to higher education, look at profit maximization (fostering less expensive courses to the detriment of those more expensive in the sciences and technology), and are not required to engage themselves in research and development activities. Chiarini and Vieira (2012) identified only around 5% of enroled students in engineering and around 3% in mathematics and ICT. Although with slightly different figures, Brazil was also identified as producing a reduced number of tertiary education graduates in STEM fields in relation to the total number of students: Brazil 14%, a figure close to the number of STEM graduates in the US (13%) but distant from the 41% of China (Craig et al, 2012). Still, authors such as De Oliveira (2005) argued that in the last fifty years the engineering field expanded its disciplinary outreach to include novel areas such as health, ecology and management, while in the last ten years, the number of engineering courses offered more than doubled and the number of engineering graduates nearly doubled.

Special education options: education for the countryside

Education for the countryside has specific programs offering courses of professional qualification and schooling for young farmers which have not concluded fundamental education. This program is particularly relevant to foster education in rural communities, which tend to have a much lower average education than the urban communities. The participating farmers receive a monthly grant and have to attain a 75% presence in classes. The degree takes two years, and it is divided between theoretical classes in school and practical in the agricultural communities. In 2009, 24 thousand placements were assigned to this program.

Special education options: Quilombola education

Quilombos is a common designation to slave communities that was formed of escaped slaves. There are approximately 1,209 Quilombola communities spread throughout Brazil, except in a few states. Most of these communities are in the state of Bahia (229), Maranhão (112), Minas Gerais (89), and Pará (81). Studies made on these communities have showed that educational units are far from the Quilombola residential areas where the students are, and that these units are precariously build (usually based on straw as the main building material). Also, the majority of the teachers does not have the minimum training qualifications and are too few to meet the learning demand (Dieguez, 2007). A situation where the same teacher teaches students in different levels of education is a common occurrence. Moreover, few Quilombola communities have an educational unit with the ability to offer a complete fundamental education (Pare, Oliveira and Velloso, 2007).

According to the School Census of 2010, 210,485 thousand students are enroled in 1,912 schools located in Quilombo areas. To increase the educational quality offered to the Quilombola communities, the Ministry of Education offers financial support translated into continuous training of teachers for Quilombos, improvement of the school infrastructure, and production and acquisition of pedagogic material.

Special education options: sequential courses

People that did not have access or the opportunity to enrol in Brazilian faculties and universities have the option to do sequential courses. With an average length of two years, these courses teach practical skills that the graduate is supposed to use in the labor market. The short duration of the course associated to learning practical skills makes this course relevant for people with some experience in the labor market. At the end, the student receives a higher education diploma. In 2007, the Higher Education Census identified 609 sequential courses that demanded the participation of the student in class.

Special education options: distance education

The Secretary of Distance Education, associated to the Ministry of Education, maintain several educational programs focused on technological innovation in the educational processes and learning, and for the development of techniques and pedagogic methods for distance education. These initiatives aim to introduce new concepts and ideas in public schools. The population has access to all the programs though educational institutions maintained by state and municipal governments. In Brazil the first distance education activities started in 1939, with the first educational institutions that would use the post office to send education materials and receive students' exams. In the 1970s, radio and television broadcasts started offering courses, including those related to project Minerva, supported by the federal government to help adult education. The third generation of distance learning started with the internet and ICT based social networks (Seno and Belhot, 2009).

Special education options: indigenous education

Public policies for indigenous school education were formulated by the Federal Constitution of 1988, which established the valorization of indigenous people by the Brazilian state. In 1999, the National Education Council created the National Curricula Guidelines for the Indigenous School Education, elaborated with the concern to maintain indigenous diversity. The implementation of these polices took into account principles, ideas, and educative practices discussed by the indigenous social movement since the 1970s. From these discussions emerged the concept of indigenous school education as a right, characterized by the affirmation of ethnic identities, recovery of historical memories, valorization of native languages and knowledge of indigenous people. Although several obstacles and difficulties still persist there was an improvement in the infrastructure of schools in indigenous villages, the supply of food for pupils in accordance with tribe traditions, the creation of specific pedagogic material and a quota system at universities for indigenous students. In indigenous lands, offering of basic education was promoted to train children, teenagers and adults engaged in community projects fostering the improvement of life conditions and the reinforcement of ethnic identities (Bernardi and Caldeira, 2012).

Programs supporting education and STEM education and related challenges

The Brazilian economy is evolving at a fast rate. This development, in particular in the most recent years, has been based according to some authors on a large labor force and failing dependency ratios (Queiroz and Turra, 2010). The strong economic performance is also explained by several other factors including the large injection of liquidity of the national development bank (BDNES) but also and very importantly, by the wide implementation of training courses, increased benefits of *Bolsa família*, and the concession of microcredit for people receiving *Bolsa família* (OECD, 2011). The *Bolsa família* program is a financial support mechanism for poor and extremely poor families in Brazil. The *Bolsa família* program integrates the overall policy “Brasil without poor” (*Plano Brasil Sem Miséria*) directed to the 16 million Brazilian citizens which have a family monthly income lower than R$ 70 (equivalent to 32 Australian dollars per month). While the *Bolsa familía* provides an income source, which promotes an immediate relief of the poor situation, the conditioning rules of the mechanism reinforce the access of these families to health, social welfare and education[4]. Policies such as *Bolsa família* associated with education and training programs also helped to decrease unemployment levels (Filho, 2012).

The Federal government has been implementing a systemic approach to tackle some of the educational problems that education has in Brazil. This involves an interdependence and a simultaneous investment in all educational levels, from basic to higher education. This is to be done to promote the quantitative and qualitative improvement across the whole education system (dos Santos, 2011). Particular emphasis is being directed more recently to the quality of education, since analyses of the link between education and economic growth found that the quality of education has a greater impact and implications to economic growth than just increasing the years of schooling (Hanushek, 2007). These policies have been having an effect on Brazil’s standing on the Programme for International Student Assessment - testing for reading, mathematics and literacy skills (PISA). Brazil had a positive evolution in the PISA scores since 2000, but still behind other Latin-American countries such as Chile, Uruguay or México (dos Santos, 2011).

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[4] See http://www.mds.gov.br/bolsafamilia

In terms of higher education, around 11% of the population aged between 18 and 24 years old enters higher education[5], which is a relatively low percentage when compared internationally. It shows a country in a massification process that is trying to gain momentum. In this context, increasing access and obtaining a greater equity whilst providing quality education is a central issue to education policy (Ramos, 2010). Several policies have been implemented towards providing greater access and equity based on the diversification of the higher education system with the creation of new types of higher education institutions, new types and modalities of courses, and the fostering of affirmative action (Neves, Raizer and Fachinetto, 2007).

Below, the specific problems that Brazilian education had to face recently and some of the strategies taken to tackle them are described. In doing this, particular attention will be granted to STEM disciplines and fields. This analysis focuses first on primary and secondary education, and then on higher education.

Primary and secondary education

Primary and secondary education suffer from two main challenges. The first is related to ***quality***, associated with the inexistence of classroom equipment, inadequate classroom equipment, poor teacher training, unbalanced ratio of pupil to teacher, poor cognitive skills development, high dropout-rate, and frequent retention (Cyrino and Correa, 2009; Dieguez, 2007). In the PISA exercise of 2006, in the science assessment, Brazilian pupils ranked 52nd among 57th participants. Still according to the PISA 2006 results, it was demonstrated that 60% of Brazilian pupils in the area of sciences did not have the needed competency to deal with the demands of daily life. The same conclusion could be drawn from the Brazilian results in the field of mathematics (Waiselfisz, 2009). This does not prevent Brazilian youngsters from having a great interest in science, in particular in the fields of biology as well as for the scientific method (Waiselfisz, 2009).

The second is related to ***access***, associated mainly with the restricted access to schooling for children from low-income families or those who live in rural areas and hard-to-reach areas (Pereira and Bahia, 2011). The issue of access is particularly relevant for STEM for two reasons. The first is that learning is closely associated with the family environment and support, as well as by the conditions that the family context can offer for study purposes. In terms of support even at home, Brazilian students tend to fare worse when compared to the Latin American and OECD average. For example, only 43% of students have at home a table to study (Latin America: 62%; OECD: 89%), 23% have access to educational software at home (Latin America: 27%; OECD: 53%), and 79% has his or her own calculating machine (Latin America: 85%; OECD: 93%) (Waiselfisz, 2009). The second is that while the Brazilian population shows greater interest by science in general, knowledge about it or scientific institutions is very low (90% of the population could not name a single scientific institution in Brazil). Moreover, there are major variations in terms of the interest and knowledge on science according to educational level and income, where those with lower levels of education and income know very little or have interest in science (Cunha, 2009).

Challenge 1 - Quality

Strong differences exist between the private and public sector in terms of quality and attendance. Private schools are usually better equipped and organized than those in the public sector, which suffer from an inadequate infrastructure and classroom basic and

[5] http://portal.mec.gov.br/index.php?option=com_content&task=view&id=12041

didactic equipment. In the public sector the quality and training of the teachers also tends to be lower than in the private sector, and the curricular coverage and learning by the students tends to be substandard. Didactics and learning methodologies are teacher-centered, consisting of the memorization of information and facts. They are not student centered fostering a more creative and autonomous learning environment. Due to the fact that the number of teachers is still low, and the ratios of students to teachers are unbalanced, those attending the free-public schools, usually the children of poor families, face greater difficulties. In this framework, the learning support is inadequate, and students from poorer families have a greater likelihood of grade repetition, retention and dropping-out. Brazil suffers from high repetition and drop-out rates in a similar fashion to other Latin American countries (Dore and Luscher, 2011). The Brazilian drop-out rate is around 25%, lower than the 33% of Latin-America, but the repetition of grades in Brazil is higher. Around 22% of Brazilian secondary students have to repeat grades while this figure rests at 12% in Latin-America. Still, even the students that overcome these difficulties experience further hardships in faring well in the vestibular (the exam to access the universities), which requires science and mathematics knowledge that can only be obtained by a quality-driven education.

Inadequate, obsolete and poor infrastructure associated with teachers without enough or proper training, high rates of teacher absenteeism, and scant use of classroom time is one of the reasons explaining why funding does not correlate with higher learning quality in Brazil (Dieguez, 2007). These reasons also explain the decline in reading and mathematics abilities, high drop-out rates, and high grade-repetition rates (Sandoval, 2012).

In the face of these challenges, strategies were taken at state, municipal and federal levels to improve the quality of primary and post-primary education by enabling easier access, better teacher training, and measures to decrease the high repetition and dropout rates. Among these are:

- High quality federally supported teacher training programs: The new Education Development Plan 2011-2020 involves a system of policies to improve the quality of teachers (a redefined national exam, improved pre-service teacher training and recruitment of new teachers must be through an organized and transparent concurso, and the establishment of a clear teacher career path) (dos Santos, 2011).

- Expansion of federal schools with the programs such as *Mais Educacao* (More Education program). This program involves several ministries and aims at increasing the educational offerings in public schools through optional activities related to the main areas of interest such as pedagogical support, environment, sport, human rights, culture and art, digital culture, prevention and promotion of health practices, educational communication, and scientific and economic education[6] (see also Estevâo, 2011)

- Supporting innovation with programs such as *Fundescola*: this program promotes a set of actions towards the improvement of quality in fundamental education. It fosters the permanence of children at public schools, and their schooling, particularly in the less developed regions of Brazil. It promotes, in a partnership regime and social responsibility, the efficiency and equity in fundamental education in these regions by offering services, products and technical and financial assistance focused on learning by doing methods[7].

[6] http://portal.mec.gov.br/index.php?Itemid=86&id=12372&option=com_content&view=article/

[7] http://www.fnde.gov.br/index.php/fundescola-acoes

- STEM Brazil - cognitive skills development: Launched in August 2009 by Worldfund[8] in three public high schools in the city of Recife, state of Pernambuco (northeast of Brazil) and also in the state of Ceará (two of the least socially and economically developed states of Brazil). By the following year, the program had expanded to 21 high schools in Pernambuco state alone, impacting 170 teachers and at least 5,000 students. Based on the success achieved to date STEM Brazil is expected to continue to grow in scale, not only in the northeast but in the whole country.

  Worldfund deemed this program for Brazil as critical based on the PISA 2006 results which reported that more than 40% of 15 year old Brazilian students performed at or below the lowest marks of science assessment. The same report indicated that Brazil ranked in the bottom 10% of all the nations participating in PISA. The implication of these results is that poor students are not gaining the needed competencies to enter university (as other studies have also found) or to be employed in science and technology related jobs. The focus of this program was thus to target public-schools, which are overwhelmingly attended by the poorer strata of the population, but also by ethnic minorities, that represent the risk groups and also the ones that have the lesser chance to attend tertiary education[9].

  The program features contextual math and science project-based learning emphasizing both academic and practical employability skills. Spanning all three years of middle education (high school), STEM Brazil focuses on teacher training, critical-thinking, and forming close bonds between the teacher and the students. The overarching goal is to engage students in a first-rate math and science program that prepares them either for tertiary education or for the job market demanding technical skills. This is done by: 1) Providing 180 hours of intensive teacher training workshops (over the course of 18 months) in each of five subject areas: Biology, Chemistry, Math, Physics, and 21stCentury skills; 2) Emphasizing advanced project-based study that reinforces state curriculum requirements in each subject area; 3) Exposing students to career options related to math, science, technology, and engineering as well as life and job skill training; 4) Delivering in-person training to math and science teachers to equip them with interactive teaching techniques and learning modules that emphasize critical and creative thinking over rote memorization; and 5) Connecting the science and math curriculum to the engineering and technology sectors of the Brazilian economy, where there are significant job opportunities.

  A critical component of the program is to further the training of teachers in participating methodologies. This is achieved through the participation of teachers in training seminars, where they learn how to teach more effectively, meaningfully, and appealingly (to students) in mathematics and natural sciences.

- Digital inclusion programme: This program – associated with the Education Development Plan developed by the Ministry of Education in 2007 – aims to enhance the quality of education by installing computers and multimedia laboratories in all public schools, and also by producing multimedia digital content to support learning activities of teachers and students through the *Portal do Professor* (teacher’s portal). This program is important and is expected to be continued as data from the Brazilian Internet Steering Committee (ICT Education 2010) indicates that each public school has on average 23 computers, but only about 18 of those are actually installed and in use due to maintenance reasons. This in a country where there is an average of 800 students per public school. In terms of broadband the

[8] http://www.worldfund.org/index.php/US/about-us/our-story/who-we-are
[9] http://www.worldfund.org/index.php/br/our-programs-br/stem-br

situation is better: broadband is present in 87% of schools which have an Internet connection[10]. As a part of the Digital Inclusion Program, the world's first educational holodeck was implemented at pre-K to middle school campus of *Colégio Atual*, a school in Recife, Pernambuco, Brazil in 2010. The holodeck is a bare room that, through custom interactive computer software and hardware, can become, for example, the flight deck of an interplanetary spacecraft. The purpose of this room is to create challenging missions in which children use their skills in the STEM (science, technology, engineering, mathematics) subjects to complete a journey. For example, on the way to Mars, the spacecraft may start to leak air, and the students need to design a way to repair the hole. The emphasis is on creative problem solving, not just demonstrating content knowledge[11].

- Technical and vocational programs - Minas PEP (*Programa do Ensino Profissionalizante*): The largest and most promising approach to date is the *Minas Gerais*' innovative voucher program, called PEP. In an effort to diversify and expand the technical and vocational training options for youths and young adults, the state launched the secondary-level voucher in 2007. Under the program, the state pays the tuition for students to attend any state-accredited training program, whether offered by a private school, municipal school or industry- based centre. The courses are in general 14-24 months long and often organized in partnership with employers, which help to guarantee the relevance of the skills being taught. They also often include a commitment from the firms to hire the graduates over the next 5 years. A good example is the new training center in "Sete Lagoas", specializing in metal mechanics and electronics. According to a World Bank report, the project demonstrated, albeit still on a rather small scale, that participatory, demand-driven mechanisms can effectively work to promote both education and employment (World Bank, 2010; Gomes, 2008).

- The *Ceará* Basic Education Quality Improvement Project aims at promoting greater equity, and quality of education services, both in terms of the academic achievement, and learning environment. The program implements in-service and continuing teacher development programs, and raises academic qualifications of teachers, both at state and municipal schools, introducing effective teaching practices. Additionally, it supports non-formal early childhood development programs, accelerated programs for over-age students, expansion of access to education through televised educational programs (TELENSINO), and increased accessibility for dropouts, parents, and young workers (age group 15-39 years). The Contextualized Education (*Educação Contextualizada*) included funded technical assistance, consulting services, and teacher training, including teaching-learning materials, and evaluation/administrative expenses. It further fostered school autonomy strategies, and strengthened institutional arrangements, through schools' reorganization, implementation strategies, studies, and impact evaluations, including social participation and mobilization[12].

- The São Paulo Basic Education Quality Improvement Project: The state of São Paulo offers a good example of a comprehensive approach to fostering educational quality and learning, pursued with sustained political commitment. The state saw its *Índice de Desenvolvimento da Educação Básica* (IDEB), i.e., basic education development índex[13], at the primary and secondary levels increase since 2005, due

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10 http://www.cetic.br/tic/educacao/2010/index.htm
11 http://www.tcse-k12.org/press/holodeckPress.pdf
12 http://documents.worldbank.org/curated/en/2008/12/10271444/brazil-ceara-basic-education-quality-improvement-project
13 http://portalsme.prefeitura.sp.gov.br/Projetos/nucleo/AnonimoSistema/MenuTexto.aspx?MenuID=32&MenuIDAberto=15

to a large extent to this program. The core of the São Paulo Basic Education Quality Improvement Project strategy underlines five main lines of action.

First, a major reform of the curriculum was made in 2007. It set clear learning standards for each grade and subject at the primary as well as secondary level and launched the development of high-quality learning materials for students and teachers. Second, in the mid-1990s São Paulo was the first state to address the problem of high repetition and age-grade distortion through accelerated learning programs. Although repetition rates have declined (in part through teacher development courses focused on refuting the belief that excellent teaching means high rates of student failure), the state continues to offer well-designed, targeted programs aimed at students who have fallen behind. Third, for over a decade, the state has emphasized the construction of full-day secondary schools and has reduced the share of secondary students in night schools from close to 70 percent in 1995 to 44 percent in 2009. Fourth, from 2008 through 2010, innovative reforms discussed earlier (pay for performance and tests of teacher content mastery) have created incentives for school improvement and a higher threshold for teacher quality across the system. Fifth, in 2010, the state launched a partnership with three state universities to develop a wholly new approach to in-service training for secondary school teachers, called REDEFOR (São Paulo State Teacher Training Network).

A final innovation also serves as a cautionary tale of the difficulty of sustaining education reforms. An innovative language voucher program launched in 2010 permitted São Paulo state secondary students to take one year of intensive English, Spanish, or French instruction at any certified language academy they chose. The innovative program capitalized on the abundance of language institutes, such as Berlitz, that have long catered to private demand. Students could take courses on their own schedules, and the quality of the instruction was considered superior to that available in the state schools themselves. However, the program was not popular with the teachers' union, which viewed it as a threat to its own stock of foreign language teachers. After a change of political leadership in 2011, the program was cancelled (Bruns, Evans and Luque, 2012).

- Pernambuco's *escolas de referência* (reference schools): In 2007, Pernambuco partnered with a group of companies committed to improving education to convert 10 existing secondary schools into a new model of full-day schools with high-quality construction. By 2010, the program had expanded to 60 full-day and 100 half-day secondary schools; by 2011, it reached a total of 174 schools (Bruns, Evans and Luque, 2012).

- *Jovem de Futuro*: This program, supported by the *Instituto Unibanco,* is a creative program to improve the quality of public secondary schools by promoting school autonomy and results-based management. Participating schools receive technical and financial support to design and implement their own school improvement strategy. Each school receives a grant of Rs 100 per student per year in incremental financing (roughly 10 percent of annual costs per student) to support the plan, as long as it aims at achieving a 40 percent reduction in student dropout and improvements in average math and Portuguese scores (on the SAEB standardized tests). Schools have autonomy to choose from a broad menu of interventions in constructing their plans, ranging from incentives for teachers, to new computers, building upgrades, learning materials, extracurricular cultural activities, or reinforcement classes. The program has been piloted in four states (Rio Grande do Sul, Minas Gerais, Rio de Janeiro and São Paulo) in a total of 86 schools, impacting 69,000 students (Bruns, Evans, Luque, 2012).

- Municipal approaches to battle grade repetition and dropping out of school (mainly for children coming from low-income families): National household survey (PNAD) data reveal that it takes children from the lowest income quintile, on average, three extra years to complete primary school. They have the lowest primary and secondary school completion rates, because the opportunity costs of remaining in school grow with each year of repetition until they become prohibitive. A large amount of the program innovation going on in Brazil today - much of it supported by influential foundations - is aimed at developing effective remedial learning programs and one of them is the innovative approach launched by Rio de Janeiro municipality in 2009. It is a two week period of system-wide *Reforço Escolar* (Schooling reinforcement). All students are tested and those not ready for the next grade receive an intensive two learning reinforcement course (Bruns, Evans and Luque, 2012). In 2010, the program provided special math and reading reinforcement to more than 200,000 students.

- TELECURSO programs by *Fundação Roberto Marinho*: The *Fundação Roberto Marinho* has developed a number of programs geared to helping over-age students in the last three grades of primary school and in secondary school get back on grade level. These programs use one specially trained teacher, supported by video/DVD programs, to teach an accelerated learning course across all subjects. The pedagogical approach emphasizes classroom discussion to ensure that students are engaged and internalize the material. The programs manage to condense the last three grades of the primary school curriculum into just one year and the three-year secondary cycle into 18 months. The programs have been adapted in several states (e.g. state of Rio de Janeiro) and municipalities, such as Acre, Amazonas, Pernambuco, and the municipality of Rio de Janeiro.

- *Se Liga*: For younger students, the Instituto Ayrton Senna has developed the program *Se Liga* (Get Connected) to help prevent age-grade distortion by ensuring that children in early grades who have not mastered basic reading and mathematics skills get extra help. For young children who can read but are at risk of grade failure, the institute developed the program *Acelera Brasil* (Accelerate Brazil), which delivers two years of content in one year. This program is being used, among other places, in the states of Paraíba, Piauí, Tocantins, and the federal district (World Bank, 2010; Bruns, Evans and Luque, 2012).

Challenge 2 - Access

Fostering access to primary and post-primary education, especially to children from very low and low income families, or those children living in hard-to-reach places, in addition to raising literacy rates, has become a key guideline of Brazilian educational and social policy. Some of these policies are described summarily below:

- *Bolsa Escola* (School Grant) and *Bolsa Familia* (Family Grant): Launched in 1995 and evaluated throughout the years, *Bolsa Escola* was a grant that was conditional only on school attendance. It was first implemented by the Mayor of Campinas in the state of São Paulo, José Roberto Teixeira, and idealized by Cristovam Buarque. Its purpose was to give the families of youngsters and children extra funding (through a grant) as long as these families would keep them at school. Not long after, other municipalities and states adopted similar programs. The broadening of this policy to become a federal grant came to be during the government of Fernando Henrique Cardoso in 2001. It benefited more than 5 million families in Brazil, until it was absorbed by the *Bolsa Família* of Lula da Silva government in 2003.

  In 2003, president Lula da Silva formed Bolsa Família by combining *Bolsa Escola* with *Bolsa Alimentação and Cartão Alimentação* (all part of Lula's anti-hunger program) and *Auxílio Gas* (a subsidy to compensate for the end of federal gas subsidies). This meant the creation of a new Ministry – the *Ministério do Desenvolvimento Social e Combate à Fome* (Ministry for Social Development and Fight Against Hunger). This merger reduced administrative costs and eased bureaucratic complexity for both the families involved and the administration of the program. *Bolsa Família* currently gives a monthly stipend of 22 reais (about 10 Australian dollars) per child attending school, to a maximum of three children, to all families with per-capita income below 140 reais a month (below or equal the poverty line). Furthermore, to families whose per-capita income is less than 70 reais per month (extreme poverty), the program gives an additional flat sum of 68 reais per month. This is called the Basic Benefit, and has no conditions (Decree nº 5.209, of the 17th of September 2004 – Regulates a Law-010.836-2004 – Bolsa Família Program)[14].

  Many scholars have demonstrated that this program had a strong impact in increasing enrolment of pupils to primary school and in reducing child dropout during the school year (de Janvry, Finan, Sadoulet 2007; Glewwe, Kassouf, 2010).

- Creative programs for children in rural areas *(Asas da Florestania)*: An important source of disparity in educational attainment is location. Up until today, there is a big disparity in schooling attainment between urban and rural children. Among rural children who manage to complete primary school, a relatively high share continues on to secondary school, and they tend to complete secondary school at the same rate as children in urban areas. These patterns confirm a central challenge of ensuring adequate schooling quality and increasing the primary completion rate in rural areas (Bruns, Evans and Luque, 2012).

  Due to these problems, some states have embraced home-based models of education as the most viable ways to provide effective services in a rural setting. Acre is one of these states. A state with 700 thousand inhabitants with 88% of its land covered by forest and located in the middle of the largest tropical forest in the world: Amazonia. Therefore, it is a region with very dense vegetation with several rivers with difficult fording, and periods of very intense rains lasting for several

[14] http://www.mds.gov.br/bolsafamilia/

months (often more than six months). About 40 thousand families live in isolated areas or with difficult access, where one can only reach by plane, boats or jeeps (Toassa, 2006). The program *Asas da Florestania* is a program focusing on these isolated communities. The curricula is the same as the one taught in the regular teaching, but applied in modules and the classes are taught by a single teacher[15].

Results from these programs: These programs helped the expansion of schooling in Brazil and with it, a vast improvement in the formal education of the labor force over the past 20 years. This has led to increased income equality and the slow build-up of a middle class. Noticeably, few of these programs were solely focused on promoting STEM as an end in itself. Rather, priority was given to increasing schooling years (in a comprehensive way), reducing poverty, improving the quality of teaching through programs focused on teacher training, class organization and pedagogy, infrastructure and broadening access to larger segments of the population. Some figures evidence the impact of these programs. In 1993, about 70% of the working population aged 26-30 years old had less than eleven years of schooling while today this number rose to 40%. Notably, the number of children who completed primary education has increased from about 42% to 71%, while the completion of secondary education rose from 28% to 55% (see for example Bruns, Evans and Luque, 2012).

Higher education

Following the trend of primary and secondary education in Brazil, one of the challenges that higher education suffers is related to **access** to higher education which continues to be low (Borges and Carnielli, 2005). This is **interlinked with quality issues**. The other challenge that was identified relates to the need to increase STEM skills at tertiary education level and **foster STEM education**. This is particularly relevant in terms of boosting the Brazilian scientific and technological base and satisfying the labor market need for STEM skilled workers (in order to ensure the country's sustainable growth). It is noteworthy to underline the investment that has been pursued also by the Brazilian government in enlarging the number of higher education institutions offering tertiary education. In recent decades, 10 new universities were opened where distance learning practices and short technological degrees were encouraged, in addition to the creation of 48 branch campuses of public universities, and the restructuring of the Federal universities through the REUNI program since 2007 (see below).

In Table 1, one can observe than other than the increasing number of students in Brazilian higher education, there has been also an increasing number and percentage of students studying in STEM related courses from 2001 to 2011. In 2001, there were 584 thousand students enroled in STEM while this figure more than doubled to 2011, when the number of enroled students in STEM reached 1.3 million.

[15] http://florestania2010.blogspot.pt/2010/12/projeto-asas-da-florestania-acre.html

Table 1 – Number of enroled students in Brazilian higher education (presential courses only), 2001 and 2011

Fields of science (as organized by the Brazilian government)	2001		2011	
	Enrolments	Percentage	Enrolments	Percentage
Education	653,813	22%	926,641	16%
Humanities and Arts	99,926	3%	150,378	3%
Social sciences, business and law	1,265,861	42%	2,389,313	42%
Science, mathematics, and computation	262,207	9%	404,942	7%
Engineering, Production and Construction	254,398	8%	743,523	13%
Agriculture and Veterinary	67,533	2%	153,447	3%
Health and well-being	363,466	12%	850,109	15%
Services	61,980	2%	111,414	2%
Total	**3,030,754**	**100%**	**5,746,762**	**100%**
STEM fields	584,138	19%	1,301,912	23%

Source: INEP, *Sinópses Estatísticas da Educação Superior*

Formation of mathematics teachers in Brazil (year of reference 2006)

According to INEP's report "Sinopse Estatística da Educação Superior – 2006" there were 567 higher education degrees training mathematics teachers at bachelor level and 64 bachelor in mathematics not directed towards education. Of the former group 52% were offered by the public sector mostly in state universities (162), followed by federal (111), and municipal universities (22). The number of students enroled in mathematics training degrees was 59,254, representing a growth of enrolment in these degrees of 24% since 2001. If there was a quantitative growth in terms of courses and number of enroled students, the results of the National Exam of Student Performance (ENADE) for 457 higher education institutions offering mathematic degrees show that 46.6% of them had a classification of 3 (from 1 – minimum classification - to 5 – maximum classification), 3.5% obtained a classification of 5, and 11% the classification of 1 or 2. 28% of the mathematics courses were not classified either because they had not yet graduated a single student or because the number of students was too low. This suggests that the education of bachelors in Brazil in the field of mathematics is of a relatively low quality.

Based on a curricula analysis of what is taught to bachelors in mathematics, one finds that the learning focus of mathematics students at Brazilian higher education institutions is mainly concentrated in "general knowledge of mathematics" (32%) and "specific knowledge for teaching purposes" (30%); 15% of the curricula is focused on "transversal knowledge" including new technologies, 13% on "theoretical basis" including educational systems, research and complementary activities of teaching, and 9% on physics and chemistry knowledge. In terms of time allocated to these curricula categories, 34% is focused on "general knowledge of mathematics" and 31% on "specific knowledge for teaching purposes". "Research activities" only occupy 4% and less than other categories such as complementary activities of teaching (5%). Additionally, it was found that not all higher education institutions offering the degree of mathematics had "research activities" disciplines, when the conclusion of the degree requires a written dissertation based on research. The analysis found that state higher education institutions have a higher proportion of disciplines dedicated to teaching contents for basic education than the Federal or private higher education institutions.

Challenge 1 - Access and quality

The policies affecting this challenge are divided between those directed at the private and public higher education in Brazil. The policies concerning the private sector or both private and public higher education sectors include the programs “ProUni”, “FIES”, “Embraer Institute School Access and Scholarship Fund”, and “Tax reduction to philanthropic private universities”. The policies concerning the public sector include “Open University of Brazil-distance learning programs”, “SENAI Initiative-distance learning programs”, “Expansion of technological courses at universities (*Cursos tecnológicos*)”, “Bolsa Universidade program”, “Reuni”, and “Racial quota”.

- ProUni: an innovative project of the federal government adopted in 2004, designed to expand higher education access by subsidizing private university tuition for high-performing students from low income families. Over 120,000 students per year have benefitted from ProUni since it was launched. Even though the higher education participation rate of low income students remains very low, ProUni allows for students from the poorer strata of the population to attend private higher education institutions[16].

- *FIES* (*Financing Students in Higher Education*): was created as a replacement of a former credit program in 1999. Operated by the *Caixa Economica Federal* (the Federal Savings Bank), its annual budget comes mostly from the Ministry of Education/MEC budget (70%) but also from the federal lottery (30%). The program financially supports students that are not able to pay the full costs of tertiary education. To be eligible for FIES loans, the students are required to be enroled at a private higher education institution and this institution needs to be registered with the FIES program, upon approval by the Ministry of Education (Neves, 2009).

  In 2007, the rules of FIES were changed to facilitate the entry of students in the university. The new ruling raised the limit on the amount a student could borrow from up to 50% to 100% of the tuition fee (both for undergraduate and graduate degrees). Other changes concerned the repayment, which since 2007 begins six months after graduation and the availability of the loan to students benefiting from ProUni scholarships, albeit with some financial restrictions (Neves, 2009).

- Embraer Institute School Access and Scholarship Fund (high school quality and access improvement and university scholarship/loans): The Embraer Institute has focused its activities on initiatives which contribute to the process of social inclusion through education. Its actions are developed in two main areas: 1) educational projects, targeting students in the public school network and 2) projects for improvement of the management process, focused on organizations of the civil society, non-government organizations, and public schools. Since 2008 investments were made in job training of people with special needs (in partnership with the Municipal Administration of São José dos Campos), university entrance exam preparatory courses for students from low-income families (‘Gavião Peixoto’ and ‘Nova Europa’, partnership with UNESP) and entrepreneurship (partnership with the NGO Junior Achievement, since 2002).

  A key feature of the Embraer Institute is the Embraer Scholarship Fund. This fund was created in 2005 to help support expenses with housing, food, transportation and

16 http://siteprouni.mec.gov.br/

others incurred by ex-students of the Engineer Juarez Wanderley College who are studying at universities outside the São José dos Campos region. Maintenance Scholarships are only granted to students with excellent academic performance at public universities or private ones with government scholarships (PROUNI) and who have limited financial resources that hinder them from continuing their education. The Scholarship Fund is comprised of donations from individuals and other bodies. Embraer is the largest contributor to the fund, guaranteeing up to 25% of the amounts paid out to scholarship holders. Partner companies, clients, individual donators and Embraer employees also participate. Former students from the Engineer Juarez Wanderley College are expected to contribute to the fund after graduating from college, paying back the scholarship correction for inflation variations[17].

- Tax reduction to philanthropic private universities: Private higher education institutions are given significant support. They are considered philanthropic by granting them tax exemptions. In turn, these higher education institutions are expected to invest at least 20% of their overall revenue in scholarships for low-income students. The institutions themselves define the eligibility criteria for these scholarships which may be for either full or partial exemption from tuition fees (Neves, 2009).

- Open University of Brazil-distance learning programs: As the private education sector dominates the provision of higher education in Brazil, catering for over 70% of students (MEC, 2010), there have been increasing efforts of the public system to increase its reach nationally, for example with the chartering of the Open University of Brazil (*Sistema Universidade Aberta do Brasil*, UAB) in 2006. However, the Open University of Brazil was also created to fill a major gap in the higher education sector: access. Average access to higher education in Brazil in 2007 was 10.6% of the population aged 18-24, compared to 40% in Argentina and 20.6% in Chile. Also, the 2005 School Census has shown that out of 2.9 million teachers in Brazil, 1.2 million did not attain a university degree. This is one of the reasons why the first main goal of the UAB was to increase access to higher education in Brazil *mostly for teachers*, in order to increase the quality of education at all levels of pre-higher education. In this regard Mota, Chaves Filho and Cassiano (2006) wrote that 'the level of training of teachers has a strong relationship with the achievement of the students (…), it seems natural that we design public policies that aim to increase the training to higher education level – with quality – to all teachers who are working or will work with early childhood education, fundamental or secondary education'.

  The Brazilian Open University is mostly based on distance-education, drawing on the affordances of ICTs to widen the reach of higher education in the country, free of charge or provided at minimal cost. This process is referred as "*interiorização da educação superior*" (bringing higher education to the countryside), meaning the UAB has been helping to bring higher education in Brazil further inland, far away from large cities, to places where private higher education institutions are fewer or inexistent. In addition to this objective, another relevant aim of the UAB has been to encourage investment in research and continuous professional development programs by means of distance education using ICTs to target the lack of graduate teachers in Brazil (dos Santos, 2011).

- SENAI's (National Service of Industrial Learning) Initiative-distance learning programs: SENAI is a national centre of knowledge creation and dissemination aimed at the industrial sector. Created in 1942, it is part of the *Confederação*

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[17] http://www.embraerinstitute.com/

Nacional da Indústria (CNI) system (National Industrial Confederation). It is the largest centre for professional education in Latin America. At present SENAI offers distance education courses free of charge for anyone interested in learning about six different areas of knowledge: Environmental Education, Entrepreneurship, Labour Legislation, Safety at Work, Communication and Information Technologies and Intellectual Property. The courses are offered in two distance education modalities: via printed materials and online. The courses have 14 study-hours each and are made available to the students via a virtual learning environment over a period of about 20 days. The students are assessed at the end of the course period and receive a course certificate[18]. Importantly, online courses and distance-learning programs have been critical in fostering the education of STEM fields, and in particular, of mathematics education (Matucheski, 2012).

- Business model for private education distance learning programs: this model proved to be very successful for the private higher education institutions. It consisted of offering of higher teacher-training courses through the medium of satellites. These relayed information on the basis of franchises to represent these institutions leading to the spreading of the model of viewing centres throughout the country. The University of North Paraná (Unopar), for example, launched the first course via satellite in 2001. By June 2006, it had set up 300 franchises with 700 viewing centres and over 80,000 students enroled in higher education distant learning courses (Maia, 2008).

- Expansion of technological courses at universities (*Cursos tecnologicos*): These courses are popular amongst the Brazilian population and have been experiencing an uptake in recent years. This uptake is related to an increased need of labor force in specific skills. According to the *Instituto Nacional de Estudos e Pesquisas* - INEP (National Institute of Studies and Research) the number of technological courses at universities went from 258 in 1998 to 4,355 in 2008. While the number of these courses grew by 1200%, during the same period, the number of *bacharelato* and *licenciatura* courses grew at a much slower pace (by 250%). The number of enroled students in technological courses also grew at a fast rate (fourfold) from 63,046 students in 1998 to 287,727 students in 2008 (MEC/INEP, 2009; Jucá, Oliveira and Souza, 2010)**.**

- *Bolsa Universidade* program (University Scholarship program) in the city of Manaus: This is a social and educational program aimed at conceding scholarships that cover all or part of the monthly fees of undergraduate degrees and of specific training to students from families with low income, and without the ability to fund their studies in private higher education institutions. 14 higher education institutions are registered in this program.

  The program is different than other programs supporting access and participation in higher education in the sense that the student upon graduation is not required to return the investment made on education. Instead, the student upon graduation is expected to participate in educational, social, cultural, environmental and other projects that are implemented by the city government. This way, the learned theoretical knowledge acquired in the classroom is associated with the practice in the field, complementing the learning process with classroom and field experience.

  The diverse projects promoted in the scope of this program have been fostering the social and economic development of Manaus, and the program itself became a

[18] http://www.cnisustentabilidade.com.br/docs/ING_SENAI_RIO20.pdf.

strong instrument to reduce social and income inequalities while helping to integrate qualified graduates into the labor market[19].

- *Programa de Apoio a Planos de Reestruturação e Expansão das Universidades Federais REUNI*: The Restructuring and Expansion Plan for Federal Universities (REUNI) was established in 2007 by presidential decree to broaden access and improve retention in higher education. The goals of this program are ambitious: reducing drop-out rates in higher education; increasing the number of vacancies offered, especially in the evening courses; increasing student mobility by implementing curricula and degree systems that allow students to transfer easily between institutions, courses, and programs of higher education; reorganizing undergraduate courses and updating teaching-learning methodologies to improve quality; diversifying modalities of undergraduate studies; broadening policies for inclusion and student assistance; and articulating undergraduate and graduate studies with primary and secondary schools (Decree Nr. 6,096/2007).

  This would be achieved by increasing and optimizing the use of physical structures and human resources that already exist at federal universities. Participation in the program is voluntary, but all federal HEIs are involved in the program. The REUNI program aims to gradually increase the mean rate of graduation in undergraduate courses taught by in-person instruction to 90% and to increase the current ratio of undergraduate students to faculty in such courses[20].

  Through REUNI the annual number of enrolments increased by 63%, from 148,796 enrolments in 2006 to 242,893 enrolments in 2010 (MEC data). The program however has not reached the students educational experience as it was expected to reach. The first classes of the expansion are graduating the university experienced overcrowded classes, overworked faculty, poorly equipped libraries and no laboratory classes. The Ministry also admits problems with the infrastructure, which are explained to be related to the pioneer characteristics of the program which nonetheless is considered to be a successful program[21].

- Racial quota: A plenary session of the Supreme Court of Brazil, on April 26, 2012, approved the adoption of a racial quota policy in higher education institutions across the country. This makes universities, colleges and educational institutions allocate a percentage of places for students of African and/or indigenous origin[22]. This was something that was demanded for some time by scholars and policymakers to increase the social inclusion and integration of the less favored ethnic groups in the Brazilian society (Santos, 2008).

Challenge 2 - Fostering STEM education

Many experts have raised alarms about the possible shortage of STEM talents, raising the possibility of a diminished capacity for innovation and slower growth especially in developed economies (e.g. The National Academies Press, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, 2007; Atkinson and Mayo, Refueling the US Innovation Economy; Manpower Group, Talent Shortage 2011 Survey Results). In this sense, the supply of STEM is growing rapidly in some places such as China or India, but less in Brazil. In Brazil, there seems to be a swelling demand for STEM skills to meet the demands of specific sectors of the Brazilian

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19 http://bolsauniversidade.manaus.am.gov.br/o-programa/
20 http://reuni.mec.gov.br/index.php?option=com_content&view=article&id=25&Itemid=2
21 http://www.folhape.com.br/cms/opencms/folhape/pt/edicaoimpressa/arquivos/2012/08/14_08_2012/0060.html
22 http://globalvoicesonline.org/2012/05/05/brazil-approves-racial-quotas-in-higher-education/

economy (such as business analytics, high-tech industry, gas and oil industry, design, energy and smart technologies), but the supply is far from meeting the demand. Policies fostering STEM education and engagement are the following: Science Without Borders Program, and the New methodology for engineering courses (the case of PBL). These are key programs to promote STEM education, which number and breath are expected to increase in the coming years to meet the increasing demands of growing Brazilian economy (as implicit in the National Education Plan 2011-2020). At the same time, specialized STEM courses are also offered by industry of which we highlight the PEE courses developed by Embraer[23] and BG-Group[24].

- Science Without Borders Program: Launched in 2011, Science Without Borders is a nationwide scholarship program primarily funded by the Brazilian government, with additional private sector support. The program is a joint effort of the Ministry of Education (MEC) and the Ministry of Science, Technology, and Innovation (MCTI) through their respective funding agencies – the Federal Agency for Support and Evaluation of Graduate Education (CAPES) and the National Council for Scientific and Technological Development (CNPq). Through this program, the Brazilian Government seeks to strengthen and expand the initiatives of science and technology, innovation and competitiveness through international mobility of undergraduate and graduate students and researchers (mostly in the fields of science, technology, engineering and mathematics). The mobility program aims to expose Brazilian students and researchers to international environments of high competitiveness, research and teaching quality, and entrepreneurship[25].

  As part of the Brazilian government's Science Without Borders Program to grant 101,000 scholarships for the best students from Brazil to study abroad at the world's best universities until 2014, an agreement was established with the Institute of International Education. This agreement provides scholarships to undergraduate students from Brazil for one year of study at colleges and universities in the United States. Scholarships are to be given primarily to students in STEM fields. These students will return to Brazil to complete their degrees[26].

- New methodology for engineering courses (the case of PBL) - a part of National Education Plan 2000-2010: Problem Based Learning (PBL) methodologies have been applied in computer science and other engineering fields in Brazil. These methodologies have been applied to augment the ability of students for critical thinking, proactivity and team work. This methodology started to be applied in the *Universidade Estadual de Feira de Santana* (UEFS), a state public university, and in the *Universidade Federal da Bahia* (UFBA), a public federal university[27].

Is there a need for people with qualifications in STEM in Brazil?

According to the *Confederação Nacional da Indústria* (National Confederation of Industry; CNI), there is a need for people with STEM qualifications, particularly engineers. Drawing from an analysis of two job vacancy websites in Brazil (Catho and Curriculum), it was found that in Catho there are almost 5 thousand vacancies for engineers in all industry areas and for all job positions, while in Curriculum this figure raises to more than 6 thousand. Engineering is one of the professions with most available positions for people to apply to. Brazil has 6 engineers per 100 thousand people. CNI assumes that the goal should be 25 engineers per 100 thousand people as

[23] http://www.embraer.com/pt-br/trabalhe-embraer/oportunidades/brasil/paginas/pee.aspx
[24] http://www.bg-group.com/sustainability11/Documents/2.%20Performance%20Sections/BG_SR_2011_05_Society.pdf (page 5)
[25] http://www.biotech-now.org/corporate/2012/07/brazil-reaches-beyond-borders-to-strengthen-stem-education
[26] http://www.iie.org/Programs/Brazil-Scientific-Mobility
[27] http://www.seruniversitario.com.br/cursos-graduacao/cursoSuperior.php?ac=Engenharia-de-computacao&id=44&f=159

it happens in the United States and Japan. The CNI analysis also points to the unbalanced choice of Brazilian engineering graduates for the civil engineering sector, area that requires less "technological knowledge" while other sectors such as the oil, gas, biofuel have difficulties in progressing more than they are already progressing due to the lack of qualified people. From the total 1,003,387 registered engineers, 77% are civil engineers, industrial technicians, electric engineers, and metallurgic engineers[28]. Other sectors such as those associated with harbor construction, maintenance and logistics also have a deficit of STEM people (and in this case, not only engineers). The *Instituto de Pesquisa Econômica Aplicada* (Institute of Applied Economic Research; IPEA) identified that the greatest need for engineers rests in mine engineers (focused on oil and gas), naval engineers, and IT engineers.

Another study carried out by the *Conselho Federal de Engenharia, Arquitectura e Agronomia* (Federal Council of Engineering, Architecture and Agronomy; CONFEA) found that Brazil would require at least 20 thousand new engineers per year to keep up with the fast development of the economy and the industrial sector. However, the same Council acknowledged that this would be a minimum, and a much higher number of graduated engineers would need to be trained in the years to come. The Brazilian government, through programs mentioned in this document, enabled the number of graduated engineers to increase. Still, the percentage of engineer graduates *vis a vis* the total number of graduates decreased during this period from 7% to 6%, when in other countries such as China or South Korea, these figures are 35% and 25%. Also, in comparative terms, Brazil graduates about 23 thousand engineers per year, when in South Korea this number is 80 thousand, India, 200 thousand, and in China, 400 thousand[29]. In this context, the associations linked to Brazilian industry are concerned with the fact that, according to the federal government, the Brazilian youth in STEM and engineering courses is waning, underlining that only 120 thousand vacancies are filled from the 302 thousand available at engineering schools (at tertiary education level).

In this context, a study by Sabóia et al. (2009) assessing the fit between the labor market needs and the qualifications of the Brazilian population (including its recent training) found that professional training attained a considerable importance, but remains concentrated in low technologically intensive programs, thus not having a substantial impact in increasing the training in STEM disciplines or the number of STEM related graduates to the workforce. This leads to an imbalance between the need of industry (and economy in general) for STEM graduates and the preference of students/offering of courses by the institutions. In relation to this issue, the authors also highlight that in middle education, professional training is stronger, offering a greater diversity in terms of learning options in the areas of health, industry, IT and management, but the scale continues to be small. The authors, however, predict these trends to change in the coming years mainly due to the private returns that any qualification in STEM brings to qualified workers, notwithstanding the level of education. For example, a STEM worker with a middle education qualification will always earn more than another worker with middle education, but in a non-STEM related field. Interestingly, among those professionals with greater remunerations in Brazil are those with tertiary education in physics, chemistry, statistics, biotechnology and instrumentation.

[28] See http://www.techoje.com.br/site/techoje/categoria/detalhe_artigo/1303

[29] See http://www.ipea.gov.br/desafios/index.php?option=com_content&view=article&id=1263:reportagens-materias&Itemid=39

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