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## **METROLOGY EDUCATION AND CITIZENSHIP: THE BRAZILIAN EXPERIENCE**

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**Abstract** - The XVII IMEKO World Congress presents a paper on *Metrology Education and Citizenship* that describes Brazilian experiences with metrology education at all academic levels. Based on a Master's Degree dissertation entitled METROLOGY: A TOOL FOR CITIZENSHIP recently presented at the Pontifical Catholic University in Rio de Janeiro, Brazil, it analyses education and legislation in Metrology, among other related issues, while addressing the Brazilian experience with metrology education.

This study argues that the sooner metrological concepts embody cultural patterns of human behaviour the faster civilization will reach the desirable stage of democracy, as metering and measuring may be considered effective ways of ensuring fair shares and equitable access to human rights in this new historical era, where Humankind and the Quality of Life emerge as true parameters for assessing social, economic, political or industrial development.

In order to verify the extent to which Brazilian society is committed to this new social order, two factors were considered: education and legal documentation. Legal documents were analyzed on the assumption that the law is the main driving force underpinning democratic living conditions. The following aspects were taken into consideration: Brazil's 1988 Constitution (known at the time it was promulgated as the Citizenship Constitution); the Brazilian Consumer Protection and Defence Code; and Metrology Regulations. In terms of Education, the historical path of Metrology is analyzed within the framework of formal education in Brazil, providing input for private and public policies addressing this sector. Special attention is paid to (i) an analysis of post-graduate programmes in Metrology within the overall context of post-graduation education in Brazil; (ii) educational policies and other political actions consolidating Metrology as an efficient ally for democracy and citizenship.

Attention was also given to the influence of major industrial landmarks on Brazil's competitiveness, in order to understand forces with positive effects on the social changes required to guarantee the quality of life and citizens' rights as crucial living conditions for humankind.

Keywords: Education, metrology, citizenship.

### **METHODOLOGY**

Based on the main methodology used in the Master's Dissertation supporting this paper, the current status of metrological practices in Brazil is described on the basis of two basic aspects: 1. Specific Legislation supporting Education; 2. Education in Metrology in order to check the commitment levels of both government and society to upgrading political and social living standards in Brazil.

Initially, this paper gives an overview of Brazilian education laws, which are fully described in the dissertation, in order to measure the extent to which the Government and society are committed to education.

The paper then lists a complete index of all educational experiences in metrology, including (i) government initiatives to integrate metrology with the Brazilian education system at all academic levels; (ii) effective educational efforts from private sectors and institutions making substantial contributions to upgrading metrology practice and education. A specific programme warrants special attention in this analysis, which was launched in the late 1960s by the Brazilian Government in order to endow local industry with a keener competitive edge through full commitment to Education in Metrology.

### **EARLY DAYS: MINISTRY OF EDUCATION IN BRAZIL**

Like other more industrialized countries, the history of vocational training in metrology in Brazil reflects a maturation period that is far more recent than basic and higher education. Without attempting to explore the remote past in the history of Brazilian education and identify its roots, the 1930s are selected solely to set the scene, under the Provisional Government headed up by President Getúlio Vargas. As a significant landmark, this anchors a possible reference for tracing the paths and development flows of Brazil's educational system, outlining the backdrop for an analysis of the structure of vocational training in metrology. This landmark consists of the appearance of the Ministry of the Education and Public Health Businesses. Although deserving merit for specifically mentioning the topic of Education, it did so together with the vast and important

healthcare sector, with significant demands and marked social impacts, establishing both these issues in the same ministerial portfolio.

Pursuing the development of Brazilian education, now firmly established as the President of the Brazilian Republic, Getúlio Vargas set up a new Ministry of Education and Health in January 1937. This divided education and healthcare into two separate departments, with higher education warranting an outstanding position in this hierarchy, known as the Higher Education Division.

But it was only during his second term in the middle of the century, in 1953, that the Healthcare / Education duo was split up, with the Ministry of Education and Culture established in the Brazilian Government structure. It was only more recently that the Ministry of Education appeared, in 1958 (MEC).

## LEGAL ASPECTS OF EDUCATION IN BRAZIL

Without going into the details of the Bases and Guidelines Act (LDB - *Lei de Diretrizes e Bases*), issued on December 20, 1996 as Law N° 9,394, but rather attempting to portray the Brazilian education system in order to provide the foundations and context for an analysis of the development of metrology teaching in Brazil, this paper summarizes the structural aspects related to the levels and types of education in Brazil: (i) *basic education*; (ii) *higher education* and (iii) *vocational training*, this latter directed to developing skills required in the working lives of its citizens.

### *Basic Education*

According to the Bases and Guidelines Act (LDB), Basic Education in Brazil is intended to foster the development of students, in order to endow them with the common skills required for the exercise of citizenship, endowing them with the means to progress in their work and subsequent studies. Basic Education in Brazil consists of: (i) *early childhood education*, which is the initial stage of education, designed to foster the all-round development of children up six years old, covering physical, psychological, intellectual and social aspects through supplementing the actions of their families and communities; (ii) *primary school*, lasting at least eight years in order to learn basic skills such as reading, writing and mathematics, underpinning the basic training of citizens through an understanding of their natural and social environments, as well as the political system, technology, art and values shaping society; and (iii) *secondary school*, lasting at least three years and designed to provide basic training for work and the formation of citizenship among students. This stage stresses an understanding of the scientific and technological bases of production processes for basic technological education, relating theory to practice when teaching each subject. According to the Bases and Guidelines Act (LDB) students may be trained for technical jobs at this stage in their education, provided that their general education is not neglected, with this technical training provided in secondary schools or in cooperation with institutions specializing in vocational training.

### *Higher Education*

In Brazil, Higher Education is designed to qualify practitioners in various fields of knowledge, ensuring their performance in various professional sectors while fostering the development of Brazilian society. Entry into institutions of higher education is open to candidates who have completed their secondary education or equivalent, and have been approved through a selection process.

The most characteristic activity of Higher Education consists of college or university courses at many different levels and degrees of scope or specialization, ensuring ongoing education for graduates, as described below: (i) *sequential courses*, organized by fields of knowledge with different levels of scope, open to high school graduates who meet the requirements established by the education institutions. Intended to obtain or update technical, professional or academic qualifications, or further intellectual development in the fields of the sciences, the humanities and the arts; (ii) *under-graduate courses*, providing training and qualifications in many different fields of knowledge, through classroom teaching, distance learning or a blend of both methods. The following types of diplomas are awarded to graduating students: a) *Bachelor's Degree*: qualification obtained for exercising a profession on the labour market or following an academic career; b) *Teaching Degree*: qualification for training teachers to work with primary and secondary education; c) *technological courses or college courses in technology*: these courses were set up to respond to demands for vocational training and educational upgrades, preparation and qualifications, attuned to market requirements, in situations where students are unable to spend four or five years following a conventional university course. Technology course graduates are called technologists, with university-level training who are awarded diplomas after acquiring all the necessary skills, with the possibility of obtaining an intermediate certificate after completing an interconnected set of skills; (iii) *post-graduate programmes or courses*, open to candidates with under-graduate diplomas who meet the requirements established by the educational institutions. Post-Graduate courses include: a) *stricto sensu*: Master's Degrees and Doctorates; b) *lato sensu*: specialization and upgrade courses, varying by the minimum duration in hours, with 360 hours for specialty courses and 180 hours for upgrade courses; and finally, (iv) *extension courses*, open to candidates meeting the requirements established by the educational institutions, which may be offered at the beginners, update, refresher, qualification and re-qualification levels for professional and vocational skills, with certificate awarded to graduates.

### *Vocational Training*

Also known as education for work, vocational training in Brazil is based on the principle of training workers, regardless of their schooling levels. When focused on skilled workers, this type of training may consist of specialty, refresher or upgrade courses extending their technological expertise, while the training open to other workers consists

of qualifications, re-training or update courses designed to pave the way for their entry to the market and enhance their performance in the work place. The vocational training policy proposed in Brazil is designed to strengthen the regulatory policies of the State covering metrology, as this includes a scheme that is closely linked to regular schooling, implemented through teaching institutions and the public and private sectors involved with this segment. For workers, this type of education highlights the real need for partnerships and resources provided by the companies themselves, viewed as enhancing the skills and qualifications of their workers.

Vocational training consists of the following levels of courses: (i) **Basic**, intended to qualify, re-qualify and re-train workers, taught in a manner compatible with their technical expertise and schooling levels, not subject to a regulated curriculum, with graduates awarded skilled worker qualification certificates; (ii) **Technical**, intended to provide secondary school leavers with vocational skills, and may be offered concomitantly or sequentially, taught as stipulated by law; and (iii) **Technological**, consisting of college courses in the technological area designed for secondary and technical school leavers, with graduates awarded a technologist diploma.

**OVERVIEW OF THE DEVELOPMENT OF POST-GRADUATE EDUCATION IN BRAZIL**

Taking higher education in Brazil as the starting point, as the initial Brazilian experiences in metrology education began at the post-graduate level, this paper offers a brief overview of this level of education in Brazil.

Ever since the Ministry of Education and Public Health Businesses was set up during the 1930s, Brazil’s educational system has undergone a process of steady development. Within a context of demographic growth that tripled the Brazilian population from 52 million to 170 million, in parallel to a broad-ranging rural exodus reversing the proportion of urban residents from 20% to 80%, the percentage of Brazilians registered with university courses rose from 0.1% of the population to 1.5%. This increase is more significant than it may seem in numerical terms, when bearing in mind the startling expansion in the Brazilian population, and the drop in illiteracy rates over the same period, down from 52% to 12%.

It was only during the second half of the XX century that the intervention of the State was felt to be necessary in terms of establishing post-graduate educational facilities in Brazil, perceiving that local technology was failing to progress at rates compatible with the desired pace of technical and economic development. This prompted the acceptance of some reflections grounded on the visionary efforts of a few people, stepping up the pace of Government actions that encouraged staff training, while fostering scientific and technological development in Brazil.

As a benchmark, the first two post-graduate programmes in Brazil specialized in Chemical Engineering, under the Chemical Engineering Division at the Chemistry Institute, at what was then the University of Brazil, and Mechanical Engineering, at what was then the Polytechnic School at the

Pontifical University in Rio de Janeiro, both constituting the roots of post-graduate education in Brazil. From then on, the pace at which post-graduate courses expanded in Brazil stepped up to a remarkable extent, according to the data available from the University Level Staff Advanced Education Coordination Unit (CAPES - *Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior*) under the Ministry of Education and Culture (MEC) covering Master’s Degrees and doctorates by year in all areas of knowledge, shown in Figure 1.

**Brazil: Development of Masters and Doctorate Courses (1960-1999)**

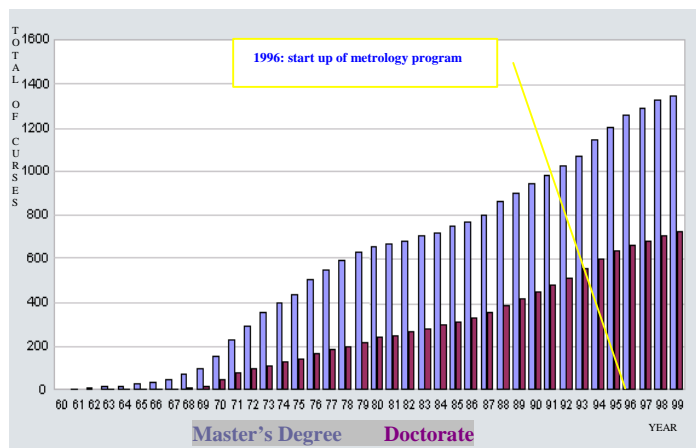


Figure 1: Development of Post-Graduate Education in Brazil, in all areas of knowledge (Post-graduation in Metrology only started in 1996, counting just for a few percent of the overall effort).

As shown in the above graph, post-graduate courses in Metrology are far more recent, launched under this name from 1996 onwards, as described in the next section.

**VOCATIONAL TRAINING IN METROLOGY**

Contrasting with this startling development in post-graduate education in Brazil, education in metrology did not undergo a slow and well-planned maturation process, with systemic growth. Instead, it arose from location-specific encouragement through Government actions linked to equally location-specific processes designed to strengthen Brazil’s laboratory infrastructure and aiming at specific targets for the nation’s scientific and technological development.

Even if unable to clearly perceive the unparalleled opportunities opening up at that time, including crucial international insertion, it must be acknowledged that the project establishing the advance campus of the National Institute of Metrology, Standardization and Industrial Quality (LNM/INMETRO - *Laboratório Nacional de Metrologia/Instituto Nacional de Metrologia, Normalização e Qualidade Industrial*) during the 1970s was sufficiently daring for that time, as this was to replace an entity that had barely managed to lay down the bases for metrological inspections in Brazil. The National Weights and Measures Institute (INPM - *Instituto Nacional de Pesos e Medidas*)

found that its project to build laboratories depended on human resources that were still being trained, confirming that many of the constraints and shortfalls in Brazil are due not to limited expertise and visionary intelligence, but are rather prompted by a lack of political will and injunctions, hobbling the development pace of major projects.

In 1975, this movement gave rise to the first initiative to train human resources in Metrology, in order to educate professionals who would head up the various primary laboratories constituting the National Metrology Laboratory (LNM) for the advance campus of the National Institute of Metrology, Standardization and Industrial Quality (LNM). A specific cooperation agreement was drawn up with the renowned Physikalische-Technische Bundesanstalt (PTB). Prior to the technical training of these professionals at the German Metrology Institute, INMETRO signed an Agreement with the Post-Graduate and Research Coordination Unit (COPPE - *Coordenação de Pesquisa e Pós-Graduação*) at the Rio de Janeiro Federal University (UFRJ - *Universidade Federal do Rio de Janeiro*) covering the implementation of a specialty course which – at that time – could well have been conceptualized as a *lato sensu* post-graduate programme designed to train engineers and physicists, supplementing and updating their basic science backgrounds and preparing the initial technical staff of the National Institute of Metrology, Standardization and Industrial Quality (LNM/INMETRO): the **Cryptonium Project**. As the outcome of the excellent efforts of the Post-Graduate and Research Coordination Unit researchers and management, in partnership with foreign researchers, this project trained two classes of professionals, in 1975 and 1976. Most of these graduates were absorbed by National Institute of Metrology, Standardization and Industrial Quality (INMETRO), consisting of some sixty students from these two classes, whose specific needs resulted in supplementary specialty courses for some of them at the excellent facilities of the National Metrology Institute in Germany (PTB), appointed to head up and lead metrology practices and laboratory accreditation activities. Now approaching retirement, some of them still remain with National Institute of Metrology, Standardization and Industrial Quality (INMETRO), completing an important training cycle for the primary metrology practitioners in Brazil.

The Cryptonium Project paid dividends in 1977, when a metrology training programme was launched for non-Brazilian university graduates, sponsored by the Organization of American States (OAS) in order to develop metrological systems in their respective countries. This programme was implemented on the INMETRO laboratory campus, divided into two training courses, and taught by professional Brazilian instructors from the National Metrology Laboratory. Given in 1977, the first course focused on legal metrology and scientific metrology, attended by twelve students; the second course was held in 1980, focused solely on industrial metrology, attended by ten students. In addition to providing other countries in Latin America with expertise that was extremely important for their development, this experience endowed the National Institute of Metrology, Standardization and Industrial

Quality (INMETRO) with extremely high status, acknowledging its technical and scientific potential, acquired partially through the Cryptonium Project and the expertise built up by its professional staff.

After a further period in the doldrums and political measures that once again hampered the development of human resources in metrology, the deregulation of the Brazilian economy highlighted the need to endow products that were MADE IN BRAZIL with ample credibility, in order to allow them to compete on demanding international markets protected by technical barriers. It was through this awareness that metrology is the only legitimate tool for removing technical barriers, which often mask unacceptable political barriers, that metrology returned to the stage as a top-priority area, warranting specific support through Government programmes designed to step up financial backing for research, introducing new criteria, mechanisms and procedures providing support for areas that were pre-defined as top-priority. This was the case with the highly successful Scientific and Technological Development Support Programme (PADCT - *Programa de Apoio ao Desenvolvimento Científico e Tecnológico*) covered by a loan agreement between the Brazilian Government (headed by the Ministry of Science and Technology) and the World Bank. This project revolutionized the development logic of this international institution, which at that time lacked any tradition in financing science and technology programme, rather preferring to underwrite only large-scale projects designed to provide infrastructure for cities and regions, building airports, cleaning out bays, and remedying the environment.

This new opportunity endowed metrology with a higher profile, and with the drive towards quality that was effectively launched in Brazil during the 1980s, depending directly on investments in other basic industrial technology functions (certification, laboratory accreditation, actions by inspection entities and conformity assessment activities) human resources training in metrology once again became a matter of much concern. This is why – for reasons that are well understood at the time – vocational training these aspects of competitiveness was rated as high priority by the Government, particularly within the context of the Scientific and Technological Development Support Programme (PADCT), which provided significant encouragement for human resources training and qualifications in MNQ through specific programmes and projects. These included the Quality Management Specialization Programme (PEGQ - *Programa de Especialização em Gestão da Qualidade*), Strategic Activities Human Resources Training Programme (RHAE - *Programa de Capacitação de Recursos Humanos em Atividades Estratégicas*) and the Metrology Human Resources Programme (RH - *Programa RH-Metrologia*), was rated as a model to be adopted by the Inter-American Metrology System (IMS) supported by a secretariat that is part of the organization of American States (OAS).

Finally, during the 1990s, metrology was understood as a crucial factor for strengthening Brazil's Federal Special Exports Programme (PEE - *Programa Especial de Exportações*). With the target of doubling Brazilian exports from 1998 through 2005, this Programme was launched on

September 8, 1998, by President Fernando Henrique Cardoso, rated as high priority and underscoring Government priorities through this Programme. Basically, the Special Exports Programme (PEE) always represented an innovative tool for boosting exports, structured on a matrix basis that interlinks production sectors with Government areas working with foreign trade and encouraging specific demands for human resources.

Similar to the development process of post-graduate education in Brazil, during the 1990s, formal metrology education resulted from planning actions implemented through a Government incentive process. This was how the **Human Resources – Metrology Programme** was set up within the context of an interministerial initiative, with the main purpose of endowing Brazil with qualified human resources in the metrology sector and meeting specific demands from the National Institute of Metrology, Standardization and Industrial Quality (LNM/INMETRO) and other laboratories constituting the service laboratory infrastructure in Brazil: (i) Brazilian Calibration Network (RBC - *Rede Brasileira de Calibração*), (ii) Brazilian Test Laboratory Network (RBLE - *Rede Brasileira de Laboratórios de Ensaios*), (iii) National Legal Metrology Network (RNML - *Rede Nacional de Metrologia Legal*) (iv) industrial laboratories; and (v) laboratories run by the healthcare, agriculture, safety, security and environment systems. These demands were analyzed through a survey carried out among these laboratories, with its findings showing the following difficulty levels experienced by Brazilian metrology laboratories: human resources (36%); machinery and equipment (29%); metrological reliability (14%) and building facilities (12%). With regard to human resources, the number of training professionals and their remuneration were the main stumbling-blocks. The Human Resources Metrology Programme also planned to produce specialized literature and promote technical and scientific events focused on metrology, which would establish a metrological culture adapted to the new demands of market economies.

In keeping with this planned strategic alignment, Phase 1 of the Human Resources Metrology Programme (1995–1998) consisted of **structuring**. It consolidated two *stricto sensu* Post-Graduate Programmes in Metrology (*PósMQI* and *PósMCI*, described below) in two supplementary areas. During their brief existence, they have already qualified over seventy students with master's degrees in metrology, in addition to research assigning high priority to solving industrial problems requiring sophisticated metrological techniques. Due to their impressive results, which were consolidated during Phase 2 of the Human Resources Metrology Programme (1998–2002), focused on **strengthening**, these Programmes were acknowledged during the last CAPES assessment covering 1999–2001. During the current Phase 3 focused on **consolidation** of the Human Resources Metrology Programme, the Post-Graduate Programmes in Metrology (*PósMQI* and *PósMCI*) have been firmly supported by the Brazilian Government through **Sectoral Funds**. This indicates a new phase encouraging the development of science and technology, ushering in a fresh

wave of optimism that focuses firmly on encouraging metrology and correlated areas.

One of these Sectoral Funds (Green-Yellow Fund) was established in late 2000, in order to underwrite cooperative research, paving the way for interaction between universities and enterprises as a powerful tool for technological development and dissemination. The interaction of these two hubs fostering the innovation development process – university and business – is quite usual in the Metrology Master's Degree Programmes (*PósMQI* and *PósMCI*) based on strategic actions and seeking solutions to a major Brazilian problems. This is turning these programmes into the nerve-centre of human resources strategies in metrology while contributing significantly to boosting investments in science and technology activities in Brazil.

#### *Recent experiments in teaching metrology*

The **Post-Graduate Programme in Metrology for Industrial Quality (*PósMQI*)** was established in July 1996 at the Pontifical Catholic University in Rio de Janeiro (PUC-Rio), mainly to serve as a tool for integrating universities and enterprises. Focused on industrial competitiveness, it is structured to set up interfaces with enterprises and other organizations seeking solutions to specific metrology problems in order to upgrade product quality and endow Brazilian companies with a keener competitive edge. During the first six months of its existence, the *PósMQI/PUC-Rio* firmed up its position by awarding 39 Master's Degrees in Metrology to practitioners and academics, on critical aspects of metrology, many of which help upgrade metering methods and techniques of interest to industry ([www.metrologia.ctc.puc-rio.br](http://www.metrologia.ctc.puc-rio.br)).

The **Post-Graduate Programme in Scientific and Industrial Metrology (*PósMCI*)** began its activities in March 1997, at the Santa Catarina Federal University (UFSC) in Florianópolis, driven by demands from professionals with ample knowledge of metrology in order to underpin the quest for quality and competitiveness in this segment among Brazilian companies. Leading to a Master's Degree, this Scientific and Industrial Metrology Course is divided into two types: *stricto sensu*: (i) Traditional Master's Degree (academic) and (ii) Vocational Master's Degree. Since it was first established, a total of 32 Master's Degrees have been awarded ([www.posmci.ufsc.br](http://www.posmci.ufsc.br)).

**Other Experiences** were prompted by the accomplishments of other universities in training human resources in metrology. The Engineering College at the São Francisco University (USF) set up its Master's Degree in Metrology Programme in 1998. However, according to the CAPES criteria (Ministry of Education) based on the expertise of its practitioners, in 2000 this institution decided to introduce the concepts and uses of metrology into the Post-Graduate Materials, Science and Engineering Programme (PPG-ECM - *Programa de Pós-Graduação em Engenharia e Ciência dos Materiais*) that was already structured. Under this new concept, this Master's Degree in PPG-ECM was defined within a single field of concentration: "Materials Characterization and Development" with four lines of research, one of which is

Metrology Applied to Materials. Consequently, instead of a specific course as originally conceptualized, the Master's Degree in Metrology is now a line of research under the PPG-ECM, focusing specifically on metrological aspects related to engineering and materials sciences. Consolidated for at least two years as a line of research for the Master's Degree in Materials Sciences and Engineering, nine of the eighteen Master's Degree students under the current PPG-ECM are working on research projects following these lines. There are also records of thirteen dissertations written under the old Master's Degree in Metrology Programme that are being re-qualified along the research line of *metrology applied to materials*.

From 1990 through 1993, the **Production Engineering Post-Graduate Programme run by the Technology Centre at the Fluminense Federal University (UFF)** signed agreements to implement this Master's Degree within the context of Technology, Innovation and Work. This opened up the field for the development of practitioners specializing in Metrology and Quality, focused on the needs of INMETRO. Through this initiative, only two degrees have been awarded, one of them to a professional working for INMETRO and the other to a professional with the Brazilian Navy. More recently (2002), INMETRO signed a new agreement with the Fluminense Federal University (UFF) to provide Management training, which cannot be analyzed, as it is still incipient.

Grounded on the basic assumption that the implementation of Doctorate Programmes in Metrology is not justified, due to its inherently interdisciplinary nature, while PhD dissertations on metrology hosted by Post-Graduate Programs in Engineering, Chemistry or Physics should certainly be encouraged, it is worthwhile mentioning the experience of the Post-Graduate Programme in Mechanical Engineering at the Santa Catarina Federal University (POSMEC/UFSC), which offers a specialization area in Metrology and Instrumentation. At the moment, there are twelve doctoral thesis in the Metrology and Instrumentation area, although noting greater stress on instrumentation rather than metrology.

There are also three projects on record implementing *stricto sensu* Post-Graduate Programmes in Metrology at the Minas Gerais Federal University (UFMG), the Federal Technology Education Centre in Minas Gerais (CEFET-MG) and the Pará Federal University (UFPA), shown in Table 1.

Following the same interdisciplinary logic, and the lack of justification for setting up specific Metrology undergraduate courses, some Brazilian universities – although only a few so far – have acknowledged the study of Metrology as a strategy for upgrading their courses, and are deciding to include Metrology as a subject in already-established under-graduate courses.

In addition to these efforts at the post-graduate and under-graduate level in Metrology, other important experiments are being firmed up at different levels of academic training. A good example of these joint actions is the implementation of the **Technical Course in Metrology** being run by INMETRO jointly with the Worker Circle State School (CECO) in response of the targets developed for Phase 2 of the **Human Resources Programme in**

**Metrology**, having qualified over thirty metrology technicians. Mirroring the success of this experience, the Federal Chemical Technology Education Centre (CEFETQ) set up its **Technical Course in Metrology for Quality Management**, in 2000. More recently, in 2002, the Technical School (ETC) at the Rio Grande do Sul Federal University (UFRG) introduced a **Basic Metrology Course** in order to meet demands for qualified professionals from local institutions and companies, prompted by new economic relationships characterized by the standardization and accuracy of industrial product measurements.

Another outstanding experience in metrology education in Brazil comes from the National Industrial Apprenticeship Service (SENAI - *Serviço Nacional de Aprendizagem Industrial*), which is the largest educational centre in Latin America, linked to Brazil's National Confederation of Industry (CNI - *Confederação Nacional da Indústria*). Its structure consists of one National Department (DN) and 27 Regional Departments, in addition to 122 international partners. In the course of its noble mission of fostering vocational training for work and providing services underpinning development and honing the competitive edge of the industrial sector, SENAI developed the **SENAI Metrology Management Programme**, which includes Metrology as a subject in all its vocational training courses. Producing, disseminating and adapting technology and know-how for Brazilian industry as a whole, SENAI provides a vocational training in many different fields, while also rendering services designed to modernize enterprises and endow them with a keener competitive edge. This broad-ranging network offers educational modules that range from industrial apprenticeship to fine-tuning professional skills, advanced vocational training, and technical, specialization and university-level courses. Over 2.8 million students register each year for the 1,800 courses and hundreds of programs offered through 293 Training Centers and Vocational Training Centers, as well as the 332 mobile units, in addition to 45 National Technology Centers (SENAITEC) and 56 Vocational Training Model Centers, which are certified under parameters of the National Quality Award.

Each of these experiences is analyzed in-depth in the recent Master's Degree Survey (ALMEIDA, 2002) characterized in Table 1.

## CONCLUSION

The significance of Metrology training lies in the logic corpus represented by this course, with marked effects on competitiveness, upgrading the quality of life and living conditions, therefore building up citizenship. This training brings together technical aspects (the oldest type of skills (the only type required through to the end of the XIX century), scientific aspects (required from the 1950s onwards), management aspects (1970s onwards) and cultural aspects that require an international viewpoint characteristic of a world with globalised markets and production processes. Considering the political stage on which all nations are now called upon to act – the so-called globalization phenomena – where new force correlations determine different ways for trade and commerce, it is natural to assume that Metrology,



as the science of measurement, will certainly help promote fair trade and boost the economy. Once abiding by agreements standardizing measurements of capacity, weight and length, countries will be able to ensure fair competition among themselves, guaranteeing universal quality of life standards.

Although world industry has already recognized Brazil's efficient progress towards meeting the standardization levels required by fair trade and commerce, the cultural foundations for the importance of Metrology for standardization in the Brazilian economy and quality of life are still frail, requiring from ample input from the government and private sectors in order to speed up this process to which the present work may have contributed.

In this context, if Education in Metrology is to be perceived as an instrument for citizenship it should not be considered only at the highest academic and scientific levels but implemented through partnership with government and non-governmental institutions, also as outreach programs assisting both laid-off workers as well as groups encouraging difficulties in obtaining specific training or lacking the conditions needed to enter the production system [11]. In this global process, education plays a leading role, particularly education in metrology, due mainly to its direct impact on the development of basic concepts of competitiveness, quality of life and citizenship.

Table 1: Global Metrology Education Efforts in Brazil

Course	Institutions	Starting Date	Results
PósMQI	PUC-Rio	1996	39 Masters
PósMCI	UFSC	1997	32 Masters
Metrology and Instrumentation: specialty area, POSMEC doctorate	USF	1998	12 Doctors
Metrology: specialty area, Master's Degree in Production	UFF	1990-1993	02 Masters
Specialty Course in Metrology	CEFET-MG	1997	20 (pilot)
Specialty Course in Metrology	UFMG	2002 project	Not yet implemented
Specialty Course in Metrology	UFPA	2000 project	Not yet implemented
Extension Course	State Universities SP	2000 pilot	30 participant
Technical Course in Metrology	CECO / INMETRO	1998	30 technicians
Technical Course in Metrology for	CEFETEQ, Nilópolis	2000	51 technicians
Basic Level Course	ETC, UFRGS	2002	29 graduands

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