

THE BRAZILIAN EXPERIENCE IN THE DEVELOPMENT OF HUMAN RESOURCES IN METROLOGY

*G. M. Rocha*¹, R. P. Landim²

Inmetro - Brazilian National Institute of Metrology, Quality and Technology
Avenida Nossa senhora das Graças, 50 - Xerém, Duque de Caxias, RJ, Brazil.
¹gmrocha@inmetro.gov.br, ²rplandim@inmetro.gov.br

Abstract: The aim of this paper is to present the Brazilian experience with metrology education at all academic levels. The principal projects devoted to the development of human resources in metrology and metrology-related areas will be considered. The main success experiences shown in this paper are the master's degree courses and technical courses in metrology, that along the years have been forming specialized human resources to supply the needs of Inmetro, Brazilian industries, metrological laboratories and Brazilian society.

Keywords: Metrology, Education, Human Resources, standardization, industrial quality.

1. INTRODUCTION

The competitiveness of a company is based on the quality of its products and this, in turn, depends on its measurement capabilities, related to the field of metrology, defined as measurement science and its applications. Besides, metrology provides substantial basis for fundamental research and development activities.

The measuring capability is directly related to the technological level of a country and it is fundamental to the process of development of emerging countries like Brazil. Measurements have become an increasingly critical tool for national and international trade, and for removing technical barriers to global trade. Therefore, the development of a well-structured national system of metrology is essential to support scientific progress, innovation, technology and competitiveness of Brazilian enterprises [1].

Between 2008 and 2011, Brazil rose from position 64 to position 53 in the World Economic Forum's Global Competitiveness Index [2]. With a Gross Domestic Product (GPD) of US\$ 2.4 trillion, Brazil is (currently) the seventh biggest economy in the world, figure 1, behind the United States, China, Japan, Germany, France and United Kingdom [3]. The Metrology plays an important role in this fast economical development and in the growth of Brazilian industry. Hence, it is fundamental for a country in development like Brazil to develop a strong national measurement infrastructure, including the development of human resources in metrology, which supports this fast

economical development and the growth of Brazilian industry.

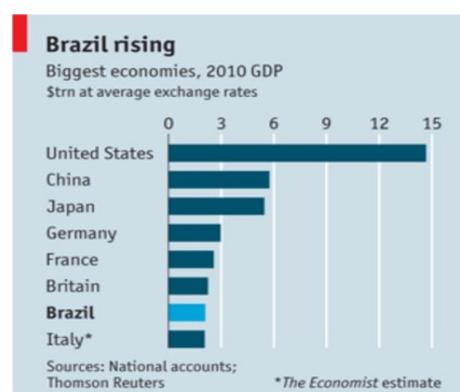


Figure 1. World's biggest economy

2. THE BRAZILIAN METROLOGY EDUCATION PROGRAMM

The metrological education presents a very recent history when compared with the history of the formal education in Brazil. Only in 1942, during president Getúlio Vargas's government, starting with the law n°. 4731, of September 23, 1942, the teaching of Metrology begun to be organized in Brazil with the implantation of the first Brazilian course of metrology, being under the responsibility of the National Institute of Technology (INT). This course started in the year of 1945, with duration of eight months, whose main objective was to offer technical preparation of personnel to supervise and to gage measurement instruments. This course of Metrology was essentially practical and the course curriculum was composed by five disciplines: mathematics, notions of physics applied to Metrology, technical drawing, practice of calibration of measurement instruments and metrology workshops [4].

Some years later, more specifically in December 1973, the Brazilian Federal Law 5966 established the National System of Metrology, Standardization and Industrial Quality. The main objective of the system, known as Sinmetro, was to provide a technological infrastructure for quality and productivity. It offers a public and private organizations structure to carry out activities related to metrology, standardization, industrial quality and

conformity assessment. This Law also established the National Council of Metrology - Conmetro, the policy arm of Sinmetro, and the Inmetro, the National Institute of Metrology, Standardization and Industrial Quality, that is the executive arm of the system. A recent law (November 2011) increased Inmetro's legal capabilities regarding fiscalization and changed its name to the National Institute of Metrology, Quality and Technology.

After the establishment of Sinmetro and the foundation of Inmetro, the Brazilian need of human resources in metrology increased a lot. So, with the goal of forming human resources that would act in its technical staff, Inmetro signed a cooperation agreement with the Coordination of Programs of Masters degree and Engineering (COPPE) of the Federal University of Rio de Janeiro (UFRJ), with the objective of implementing a specialization course, denominated Project Krypton, with the purpose of qualifying engineers and physicists, at that time approved in public contest for participation in this project and subsequent integration in the employees body of the Institution. As a result of this project two groups of professionals were qualified in the years of 1975 and 1976. Of this notable effort, the Inmetro got to absorb most of the participants of this project (about 60 specialists of those two groups). During the following years, many of those professionals complemented their specialization in the Laboratories of *Physikalische-Technische Bundesanstalt* (PTB/Germany). After returning Brazil, they assumed the position of head in the several metrology laboratories of Inmetro.

In 1995, the Brazilian government created the Human-Resources-Metrology Program, named RH Metrology, to help actions to develop human resources in metrology [5]. Its main goal was the preparation and training of human resources to work in Metrology. It was composed of three stages:

- 1st stage (1995-1998): this program was structured. The political support for it was increased. Its principles were disseminated through Brazilian society,
- 2nd stage (1998-2002): this program became stronger. Brazilian human resources needs in metrology were mapped and the first regular courses in metrology in Brazil were created,
- 3rd stage (2002-2006): this program was consolidated.

During the first two stages of the RH Metrology Program, two master's degree metrology courses (*PósMQI* and *PósMCI*, described below) were created, as well as a pioneer metrology technical course in the Latin America. This pioneer metrology technical course was established in 1998 by agreement among the National Institute of Metrology, Quality and Technology (Inmetro), the General Office of Education of the Rio de Janeiro State (SEEDUC-RJ) and the secondary school "Colégio Estadual Círculo Operário" (CECO), maintained by the government of the State of Rio de Janeiro, Brazil. The Inmetro/SEEDUC-RJ/CECO technical course, during 13 years of existence,

became a reference course in the region where it is located and it has attracted young students from various districts of the state of Rio de Janeiro. The success of this course has been so great that there is an expansion project to other Brazilian states and countries in South America [6].

3. BRAZILIAN ACADEMIC MASTER'S DEGREE COURSES IN METROLOGY

As result of RH Metrology Program was structured and established two Post-Graduate programs in metrology. i) **The Post-Graduate Course in Metrology for Industrial Quality (*PósMQI*)** - This master degree course was established in July 1996 at the Pontifical Catholic University in Rio de Janeiro (PUC-Rio), essentially 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; ii) **Post-Graduate Course in Scientific and Industrial Metrology (*PósMCI*)** - This master degree course began its activities in March 1997, at the Santa Catarina Federal University (UFSC) in Florianópolis, driven by demands from professionals with wide 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) Executive Master's Degree course.

The principal goal of this two Master Degree course is to prepare human resources to supply the needs of: (i) the National Metrology, Normalization and Industrial Quality System (Sinmetro); (ii) the National Institute of Metrology, Quality and Technology (Inmetro); (iii) the laboratories that belong to the Brazilian Networks of Calibration and Tests; (iv) the industrial laboratories and service firms; (v) educational institutions, research and technological development institutes. More detail of the courses described in this extended abstract will be presented in the full paper.

4. BRAZILIAN EXECUTIVE MASTER'S DEGREE COURSE

An Executive Master's degree is an advanced level of master's degree designed especially for mid-career executive professionals. In Brazil, the Executive Master's degree is an important branch of Brazilian Ministry of Education policy to help the development of Brazilian industries and the improvement of Brazilian products quality. The Brazilian Executive Master's degree course was created due to the need for (i) stimulation of the executive masters capable of develop technical-scientific activities and work within public interest fields; (ii) identification of potential metrological application for local, regional, national and international performance, within the private and public sectors; (iii) attending the demand for highly qualified professionals (specially in industry and other fields related to labor); (iv) human resources for socioeconomic and

cultural development of Brazil; (v) researchers and professionals capable of creating, disseminating and applying scientific knowledge in the productive processes of manufacturing goods and offering services according to the Brazilian industrial policy; (vi) closer relations between universities and the productive sector. Like other more industrialized countries, the history of executive training in metrology in Brazil reflects a maturation period that is far more recent than basic and higher education [7].

Inmetro's Metrology Executive Master's Degree Course main objective is to provide a high level professional education, forming qualified professionals in metrology. These professionals must be capable of acting in all sectors directly related to science of measurement, as well as to perform the functions of an aware Brazilian citizen.

4.1. Objectives of the Course

The main objective of this executive course is to provide the preparation and the development of human resources with high level of knowledge and technological competences capable of working in different sectors of metrology, like: laboratories, research centers, calibration services network and related areas. Those specialists must be capable of acting in all sectors directly related to the science of measurement, as well as to perform the functions of an aware Brazilian citizen.

Besides the general objective defined previously, this course also has the following specific objectives [8]:

- to provide human resources formation and capacitating in Metrology and Quality fields, helping the development of their skills in those fields ;
- to form professionals capable of generating knowledge and products;
- to discuss the implications of the technological innovations in the work process in the field of Metrology and Quality;
- to supply the National System of Metrology, Standardization and Industrial Quality with specialized professionals;
- to contribute to subsidize the debate on politics and processes in the extent of the performance of Metrology and Quality;
- to contribute for the restructuring process and qualification of human resources for the Politics of Productive Development (PDP), in Brazil;
- to study the partnership relationships among the public and private sectors.

4.2. General characteristics of the course

This master's degree course is a postgraduate degree course. Therefore, the admission to a master's program requires holding a bachelor's degree and relevant work experience may qualify a candidate. The general characteristics of this course are as follows [9]:

i) Admission; the access to the course is through selective process by public competition;

ii) Duration regime: the course will last between 18 and 36 months, with total workload of 1,155 hours (705 hours of theoretical content and 450 hours related to the elaboration of the conclusion work);

iii) Target public: graduate candidates (in any knowledge area), from any Brazilian state, or of any Latin-American country or Africa, preferentially professionals already active in the job market at industry or belonging to any laboratory in the Brazilian calibration services network. Because participants in the program are currently working or active in the profession, the age range and level of experience in a typical cohort class exceed those found in typical master degree classes. The Inmetro's Executive Master's Program accepts 20 students by year;

iv) Conclusion work: a dissertation or similar work it is needed for Inmetro Executive Master's Degree in Metrology and Quality course conclusion. It will have the format of traditional dissertation, about innovated product, or new technological methodologies, or solution of specific problem, or development of a new standard of measurement, in way to prove the effectiveness of the accomplished studies;

v) Concentration areas: Legal Metrology, International Articulation, Quality and Conformity Assessment, Scientific and Industrial Metrology and Biometrology.

With an Executive Master degree, graduates can have the chance to:

- Advance professionally
- Develop new skills
- Recognition of Gain
- Build a professional network
- Learn best practices in their industry, laboratory, and the company

4.3. Course Curriculum

The course curriculum was developed by a commission composed of metrology professional from Inmetro and from other research Institution and approved by the Inmetro postgraduate council. This curriculum was made according to legal guidelines defined by Brazilian Ministry of Education.

This curriculum, as well as the respective lesson plans, can be reviewed according to the market needs and the current legal guidelines. The theoretical and practical subjects are accomplished in the minimum period of 12 months and no later than 24 months, divided in 4 quarters. For the final work the student has 12 to 24 months for its conclusion and defense. The defense of the Final Work of course can occur from the sixth quarter, with approval of the previous credits. The complete course curriculum is presented in the tables 1, 2, 3 and 4. The course curriculum common for the concentration areas are: Instrumentation;

Introduction to metrology, normalization and Industrial Quality; Statistical; Uncertainty of Measurement; Introduction to Scientific Metrology; Introduction to Legal Metrology; Conformity Assessment; Special topics in Scientific Metrology; Special topics in Legal Metrology; Quality.

Table 1. Course Curriculum 1st Quarter

Code	Subjects	Total Classes Hours	Credit Points
GR-110	Basic Industrial Technology - TIB	15	1
QA-140	Quality and Normalization Fundamentals	30	2
MC-120	Metrology Fundamentals	30	2
GR-111	Statistics Applied to Metrology	60	4
GR-112	Research Methodology	15	1
AI-151	Politics of International Insertion	15	1
GR-113	Intellectual Property Right	30	2

Table 2. Course Curriculum 2nd Quarter

Code	Subjects	Total Classes Hours	Credit Points
MC-221	Instrumentation	60	4
MC-222	Measurement Uncertainty	30	2
MC-223	Introduction to Scientific Metrology	45	3
GR-214	Information System, Knowledge and Innovation	30	2
ML-230	Introduction to Legal Metrology	45	3

Table 3. Course Curriculum 3th Quarter

Code	Subjects	Total Classes Hours	Credit Points
QA-341	Conformity Assessment	45	3
AI-352	International trade	45	3
MC-324	Special topics in Scientific Metrology I	60	4
ML-331	Special topics in Legal Metrology I	60	4
QA-342	Special topics in Quality I	60	4
AI-353	Special topics in Articulation International I	60	4

Table 4. Course Curriculum 4th Quarter

Code	Subjects	Total Classes Hours	Credit Points
MC-425	Special topics in Scientific Metrology II	60	4
ML-432	Special topics in Legal Metrology II	60	4
QA-443	Special topics in Quality II	60	4
AI-454	Special topics in Articulation International II	60	4

5. CONCLUSIONS

Metrology is important not only to break technical barriers but also to make products and to offer better services, leading these to get stronger in competitive markets. However, working on activities that need metrology knowledge demands qualified professional capable of answering, in due course of time, to the sophistications and the speed of the innovations imposed by the contemporary technology. This way, the research and investment in the quality human resources education in metrology can result in important benefits for the full service to the demands of the productive sector and consequently to leverage the

development of industry. Thus, the Brazilian program of preparation of human resources for a career in metrology has been giving excellent results, providing well prepared metrologists to accredited laboratories, Inmetro, industry laboratories, R&D institutes and Brazilian society in general. As a continuation of this effort, Inmetro has started planning to launch two *stricto sensu* courses in Metrology: a mastering degree course and a doctorate degree course (which can be the first one in Latin America).

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