Thinking the future: development of metrology education in Brazil

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Abstract. Brazilian reference documents to organize actions in metrology have chapters dedicated to the education which is described as lacking fundamental metrological concepts in many qualification areas and with incipient activities of specific teaching on the theme. Such documents highlight the challenge to strengthen the knowledges of Metrology. The objective of this study was to make a survey of educational activities described on websites of institutions participating in the quality infrastructure of BIPM member states in South America. This information allowed identifying actions to develop the metrology education in Brazil. The research was classified as exploratory with the qualitative approach. Three categories were set: “Qualification” (the presence-based training courses were the highest occurrence); “Materials” (Audiovisual materials were the most published); and “Others”. Argentina was the country with the highest amount and diversity of activities. Some proposed actions were the translation of six materials; disclosure and distribution of 15 materials; extinction of the technical course in Metrology; organization of improvement/post-high school courses; feasibility of specialization qualification level; courses models of INTI’s (undergraduate and doctorate levels); and events for teacher training. Moreover, this study offers subsidies to set the strategic guidelines to consolidate and develop a metrological culture and education in Brazil.

1. Metrology education in documents from three Brazilian entities

The document “Physics for Brazil: Thinking about the Future”, published by the Brazilian Physical Society in 2005 [1, p. 140-141], emphasizes that Metrology is one of the multidisciplinary challenges to further develop physics and that the major Brazilian need in such area is to attract professionals with high scientific and technologic qualification. According to the document, the metrology area is associated with the demands of a society that intends to become fully industrialized, with a qualitative step for reaching the capacity to conceive and perform experiments, with a common and standardized language, with procedures that ensure the reliability in measurement results, with the safety and wellbeing and with the technical barriers to trading.

In the document entitled “Consolidation of the recommendations from the 4th National Conference of Science, Technology and Innovation towards the Sustainable Development” [2, p. 57] one of the recommendations is the support to qualification programs to tackle metrology challenges in new areas, such as biotechnology, nanotechnology, weather changes and renewable energies.

The document entitled “Strategic Guidelines for the Brazilian Metrology” [3-5] is published every five years since 2003 and always dedicates one of its chapters to education in metrology. The importance of metrology education and its challenges are described in four statements:
• Metrology is essential to increase the quality of products and processes with the consequent increase of competitiveness of industries and of the country’s industrial development.
• There is a blatant lack of fundamental metrology concepts in many qualification areas.
• Nowadays new qualification areas such as health, safety and environment depend on metrology knowledge areas in the utilization of sophisticated high-tech equipment and in the employment of technical regulations and standards.
• Metrology teaching activities are incipient.

Following this context, the objective of this study was to make a survey of educational activities described on websites of congener institutions participating in the quality infrastructure of Bureau International des Poids et Mesures (BIPM) member states in South America [6]. Reflecting about these activities and comparing the performance of institutions allowed identifying actions to develop the metrology education in Brazil, such as initiatives to reproduce, key institutions to create partnerships and emerging topics to develop new activities.

The research was classified as exploratory with qualitative approach, developed in order to provide an overall vision on a certain fact and is fundamental when the chosen theme is poorly explored [7].

2. Survey of educational activities

Educational activities may be developed in three “teaching ways” [8] or “education modes” [9]: Formal Education, Non-formal Education and Informal Education.

Formal Education occurs in official teaching institutions recognized by the legal system of the country, as well as the Brazilian Ministry of Education (MEC). It is the educational system that is both hierarchical and chronologically structured, with all its parts – bureaucratic and curricular – interconnected and mutually dependent [8 to 11].

The Non-formal Education is any educational activity organized out of the established formal system, with focus on serving specific users and with evident learning goals. Some of the characteristics that make it different from the Formal Education are: less hierarchy, less bureaucracy, variable duration and independent activity without the need of a sequential progression system, of an official teaching institution and of legal recognition. It is also known as non-school or extra-school education [8 to 11].

Informal Education is the process to acquire values and knowledge and to develop attitudes and skills occurring during the whole life thanks to the daily interaction experience with the environment – family, work, and leisure [8 and 10]. The experience of informal education is not intended to reach a specific public, which prevents learning goals from being evidenced and measured, thus making impossible to issue certificates attesting the development of competences.

According to this classification of educational activities, three categories were set for the research: Qualification (Formal Education and Non-formal Education); Materials (Informal Education); Others: activities diverging from the classification of the other two categories.

Member states of the BIPM located in South America are Argentina, Brazil, Chile, Colombia, Uruguay and Venezuela. [6] With the exception of Venezuela, with a click on the name of each one of the countries, one of the information categories is “Quality Infrastructure”, showing the list of all participating institutions. From the research on the websites of those institutions, all educational activities with their information available online were accounted and described.

The research identified educational activities in 24 institutions in five countries:

- Qualification: 1168 presence-based and 69 distance-based training courses; 3 technical courses, 34 presence-based and 1 distance-based improvement/post-high school courses; 82 undergraduate courses, 98 specialization courses, 76 master’s degree course and 40 doctorate degree courses;
- Materials: 276 articles, 9 magazines (207 ed.), 20 bulletins (339 ed.), 19 reports, 12 manuals, 54 books, 68 folders, 2 Newsletter (152 ed.), 46 booklets, 4 Strategic Plans, 6 Institutional Memories (37 ed.); 819 videos, 334 audios and 10533 pictures (audiovisual); 2 Posters, 1 CD Rom; 2 Didactic Sequences;
• Others: Seminaries and Lectures, Awards and Contests; Qualification Programs; Newsletter Subscription; Disclosure Space or Museum; Virtual Museum; Mobile Museum; Projects and Special Websites; Software; Games; Guided Visits; Publishing House; Radio Programs; Virtual Campus; Qualification Centers; Planning Course; “De Acuerdo Magazine” (interinstitutional).

Among the activities classified as “Qualification”, the presence-based training courses were the activities of highest occurrence. Audiovisual materials (videos, pictures and audios) were the most published ones. Argentina was the country with the highest amount and diversity of educational activities.

3. The quality infrastructure of BIPM member states in South America

3.1 Argentina
Quality infrastructure is formed by six institutions: Instituto Nacional de Tecnología Industrial (INTI), Comisión Nacional de Energía Atómica (CNEA), Ministerio de Economía y Producción (MECON), Sistema Métrico Legal Argentino (SIMELA), Organismo Argentino de Acreditación (OAA), Instituto Argentino de Normalización (IRAM).

Link to SIMELA on the BIPM’s website directs to the website of the Dirección Nacional de Defensa del Consumidor. Probably there is an error in the name of the institution on BIPM’s website, as no institution associated with the name Sistema Métrico Legal Argentino (SIMELA) was found. Link to the website of the Ministerio de Economía y Producción (MECON) directs to a website that references two ministries: Ministerio de Hacienda and Ministerio de Finanzas.

3.2 Brazil
Quality infrastructure is formed by six institutions: National Institute of Metrology, Quality and Technology (INMETRO); National Metrology Laboratory of Ionizing Radiations (LNMRI/IRD); National Observatory/Time Service Division (ON/DSHO); General Accreditation Coordination (CGCRE/INMETRO); Brazilian Association of Quality Control (ABCQ) and Brazilian Association of Technical Standards (ABNT).

Link to the website of the General Accreditation Coordination (CGCRE/INMETRO) on the BIPM’s website directed to a page in English that is not available. The research was made on the Portuguese page of CGCRE/INMETRO and it had no information on educational activities.

3.3 Chile
Quality infrastructure is formed by ten institutions: Instituto Nacional de Normalización (INN), Instituto Nacional de Salud Pública (ISP), Instituto de Estudios, Medición y Certificación de Calidad (CESMEC LTDA), Calibraciones Industriales S.A (CISA), Corporación Nacional del Cobre (CODELCO), Laboratorio Custodio de los Patrones Nacionales de la Magnitud Longitud. Nodo de la Red Nacional de Metrología (DICTUC S.A),., Empresa Nacional de Aeronáutica (ENAER), Instituto de Investigaciones y Control (IDIC), Universidad de Concepción (UDEC), Red Nacional de Metrología de Chile (RMN).

The websites of the Instituto de Estudios, Medición y Certificación de Calidad (CESMEC LTDA) and of the Empresa Nacional de Aeronáutica (ENAER) had no information on educational activities.

Link to ENAER’s website on the BIPM’s webpage did not correctly direct to the website and search for the name of the company using Google® search tool identified another address. Link to the website of Instituto de Investigaciones y Control (IDIC) on the BIPM’s webpage directed to an inactive website of the Laboratório de Força belonging to Red Nacional de Metrología de Chile (RMN). On the BIPM’s website, the link to Universidad de Concepción (UDEC) directed to the website of the Laboratorio Custodio de los Patrones Nacionales de las Magnitudes Eléctricas belonging to UDEC. In cases where the institutions of the quality infrastructure listed on BIPM’s
website are laboratories of bigger institutions, the educational activities were searched in the websites of such institutions.

3.4 Colombia
Quality infrastructure is formed by two institutions: Instituto Nacional de Metrología da Colômbia (INM) and Instituto Colombiano de Normas Técnicas y Certificación (ICONTEC).

3.5 Uruguay
Quality infrastructure is formed by four institutions: Laboratorio Tecnológico del Uruguay (LATU), Instituto Uruguayo de Normas Técnicas (UNIT), La Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE) and Laboratorios Tecnogestión del Ministerio de Industria, Energía y Minería (MIEM – LSMRI).

Considering that the institution Laboratorios Tecnogestión is part of the Ministerio de Industria, Energía y Minería (MIEM – LSMRI), educational activities were searched on the website of the ministry.

4. Results from survey related to strategic guidelines to consolidate and develop a metrological education and culture in Brazil - years 2013-2017
The results from survey were related to five strategic guidelines (i, ii, vii, viii, ix) concern Formal Education that are in force [5, p.53]:

- i. Intensify programs to insert metrology contents in disciplines of higher education and professionalizing courses;
- ii. Foster and stimulate the production and publication of literature, including didactic books, thesis, studies and researches in the scope of metrology;
- vii. Consolidate and expand professional technical teaching programs and Inmetro’s graduate programs, thus expanding the offer to society of programs related to Metrology, Quality and Technology;
- viii. Support and encourage implementation of high school level professionalizing technical courses and schools in all regions of Brazil in accordance with the Pronatec Program with focus on areas such as metrology, quality and compliance evaluation;
- ix. Consolidate the Program of Technologic Residence in Legal Metrology, which includes teacher qualification actions and the holding of specialization courses in Legal Metrology with the purpose of qualifying professionals to work in the State Institutes of Weights and Measurements (IPEM).

In order to insert metrology contents in already established subjects (Guideline i), there must be materials published on the subject (Guideline ii) to be then used as either didactic or support material, as well as teacher qualification actions (Guideline ix) to disclose materials and encourage their adoption.

The survey demonstrated 15 materials for education in metrology and quality, nine in Portuguese:

- Bulletin: “Miradas 2016. Diseño Industrial. Información teórica, de actualidad y casos prácticos, vinculadas con las distintas áreas del diseño” (INTI);
- Manual: “Introducción a las Tecnologías de Gestión”, “Introducción a las Tecnologías de Gestión. Manual Módulo 2” and “Introducción a las Tecnologías de Gestión. Manual Módulo 3.” (INTI)
- Book: “Sistema Internacional de Unidades: SI. — 1ª Edição Brasileira da 8a edição do BIPM”, “Sistema Internacional de Unidades Suplemento 2014: Actualizações para a 1ª Edição Brasileira (2012) referente a 8ª Edição do BIPM (2006) da Brochura SI”, “Vocabulário Internacional de Metrologia: Conceitos fundamentais e gerais e termos associados (VIM 2012)”,” Avaliação de dados de medição – Uma introdução ao “Guia para a expressão de incerteza de medição e a documentos correlatos –INTROGUM 2009”;

“Avaliação de dados de medição - Guia para a expressão de incerteza incerteza de medição –
The actions are:

- one Technical course: Metrology (INMETRO)
- 26 Improvement / Post-High school: “Asistentes en calidad con orientación en Metrología”, “Calidad en la gestión integral de los Procesos”, “Calidad y seguridad de sistemas de información” (INTI); “Fundaments on radioprotection and metrology” (LMRI/IRD); “Gestión de la calidad para el sector educativo”, “Sistema de gestión de calidad e inocuidad en la industria de alimentos”, “Gestión de calidad MECI-GP 1000”, “Sistemas de gestión de calidad NTC ISO 9001: 2015”, “Sistemas de gestión integrados HSEQ. NTC ISO 9001:2015, NTC ISO 14001: 2015 y NTC OHSAS: 2007”, “Sistema de gestión ambiental SGA. NTC ISO 14001: 2015”, “Sistemas de gestión seguridad industrial y salud ocupacional”, “Sistemas de gestión seguridad industrial y salud ocupacional. Decreto 1072 2015”, “Básico sistema de gestión de calidad para dispositivos médicos - ISO 13485”, “Acreditación IPS”, “Gestión de la seguridad del paciente”, “Gestión de la seguridad del paciente con énfasis en habilitación”, “Acreditación para entes territoriales”, “Responsabilidad médico legal”, “Gestión de la calidad modelo ISO 9001-virtual” (ICONTEC); “Técnico en Gestión de la Calidad UNIT-ISO 9000”, “Supervisor (Asistente) en Gestión de la Calidad UNIT-ISO 9000”, “Especialista en Gestión de la Calidad UNIT-ISO 9000”, “Supervisor (Asistente) en Gestión de la Seguridad y la Salud Ocupacional UNIT-OHSAS 18000”, “Especialista en Gestión de la Seguridad y la Salud Ocupacional UNIT-OHSAS 18000”, “Especialista en Gestión Ambiental UNIT-ISO 14000”, “Especialista UNIT en Recursos Humanos para Sistemas de Gestión” (UNIT)
- two Undergraduate programs: “Ingeniería Industrial con orientación en eficiencia y calidad industrial” (INTI); “Diploma Superior en Sistemas UNIT de Gestión” (UNIT)
- six Specialization: “Calidad industrial en alimentos”, “Calidad Industrial”, “Tecnología y Gestión de la Seguridad contra Incendio” (INTI); “Innovación y Sistemas de Gestión”, “Implementación y Auditoría Interna de Sistemas Integrados de Gestión”, “Gestión de Calidad y Acreditación de Laboratorios Clínicos”. (UDEC)
- four Masters: “Calidad Industrial” (INTI); “Metrology and Quality” (INMETRO), “Radioprotection and Dosimetry” (LMRI/IRD); “Gestión Integrada de Medio Ambiente, Riesgos Laborales y Responsabilidad Social Empresarial” (UDEC)
- two Doctorate: “Calidad y Innovación Industrial” (INTI); “Radioprotection and Dosimetry” (LMRI/IRD)

5 Conclusion: basis for a project on metrology education in Brazil

Even though it is necessary to reach deeper knowledge on all materials and qualifications existing in the institutions, the survey enabled the identification of some actions capable of being used as basis for a project focused on metrology education in Brazil. The actions are:

- Extinction of the technical course in Metrology of INMETRO and the organization of improvement/post-high school courses: the only occurrence of a technical course in Metrology (INMETRO) may indicate that this educational level is not adequate to a specialized qualification. The amount of courses in improvement/post-high school level shows this level better for a specialized metrology education.
• Undergraduate level by means of a course model of INTI’s “Ingeniería Industrial con orientación en eficiencia y calidad industrial” in two modes - a new qualification in Engineering and discipline ideas to integrate the already existing qualification curricula.

• Improvement specialization courses: graduate courses offered by quality infrastructure institutions in Brazil fall under the masters and doctorate levels. The six specialization courses identified at INTI and UDEC demonstrate the feasibility of such qualification level.

• Research about qualification events to capacitate professors and the doctorate in “Calidad y Innovación Industrial” from INTI: they concern the initial and final steps of a formal education path in metrology and quality. However, there was not much information on the websites.

• Translation for six materials into Portuguese and disclosure and distribution of all 15 materials identified as hard and soft copies.

INTI is a key institution to create partnerships and knowing better his initiatives can be the first step to establish the interchange between congener institutions and to launch Brazilian education in metrology and quality.

Moreover, this study offers subsidies to set the strategic guidelines to consolidate and develop a metrological culture and education in Brazil for the next five years - period between 2018 and 2022.

6. References

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