

Partnership in Metrology Education for Strengthening Alliances between University Level and Technical High School Level

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Abstract - For decades Scientists, Engineers and Technicians have been concerned with technology, quality of industrial products, and processes in order to satisfy and meet customer demand. Therefore, procedures to produce quality products and process in an industrial firm should always rely on rigorous tests and measurements. The quality of these measurements is basic in a good Metrology. That is why it is imperative to have enough professionals with strong Metrology knowledge available to meet the new reality where technological changes are coming faster and faster.

In this paper, our main objective is to improve the degree of understanding in engineering education in Metrology. To achieve this, we propose to strengthen the necessary alliances between the University Level (Third Degree) and the Technical High Schools (Technical Second Degree) in order to make them both bring about the indispensable subsidies to quality and industrial competitiveness. The subject is dealt in a case study involving the Federal Technical High School of Campos (ETFC - Escola Técnica Federal de Campos/RJ), State of Rio de Janeiro and the Master Degree Program in Metrology for Industrial Quality of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Brazil. We conclude the paper with a set of recommended actions to better integrate the Third Degree in Engineering and the Technical Second Degree in Metrology education.

Basic Considerations

*It is necessary to reflect for measuring
and not to measure for reflecting*
Gaston Bachelard
The Formation of the Scientific Spirit

The Engineer's and Technician's of Second Degree traditional perception is whome looks for to satisfy the humanity's material needs. Its field is essentially the industry, the consulting firms, the laboratories of tests and the specialized workshops. The technological, industrial and commercial revolution that is transforming the world on these last two decades, changed this vision.

The diversity and the complexity of industrial products increased in considerable proportions. The progress of the production methods reduced the prices and expanded the possibilities of uses. The opening of frontiers allowed the nets invigoration of transnational companies. In all the technological fields, gigantic progresses were observed and the generated products benefitted of the same ones. The industry moved completely its nature: the computer science invaded the offices, the robotized assemblies multiplied, the integrated production and the flexible workshops became imperatives of the productivity and of the competitiveness (LANGE, 1993).

In the current conjuncture, four imperatives are imposed to our economy, to our Schools of Engineering and Technical Schools of Second Degree and to our Companies that recruit them: the quality, the innovation, the opening on the world and, finally, essential condition to the accomplishment of three first, the valorization of specialized human resources, inseparable of the dialogue and social

negotiation.

The present article intends to emphasize the innovation's deficit that is observed in the relationship of the Technical School of Second Degree with the University, in the specific field of Metrology for industrial quality and, to suggest recommendations originating from the reviewing of all its educational system oriented to Metrology, in an moment which the nation is conscious of reviewing all its educational system, in particular the Engineers' and technician's of Second Degree education (**PRODENGE**¹).

Metrology: Technical Base of Quality

The evaluation of the technical quality of the production processes should be based in a quantitative measurement *metrologically reliable*. To obtain a metrological reliability that guarantees the technical quality of the production processes, it is not enough that the equipments are traceable to reference standards, that the procedures are normalized, that a continuous evaluation of the measurement process is made. It is still necessary to assure that the professional involved directly with the measurement has the technical capacity to evaluate metrologically the results of the measurements. Those conditions show the importance of the acquisition of metrological knowledge by the future Engineers and Technicians of medium level in an integrated way. The metrological evaluation of the measurements is still a theme not very treated in the Engineering Schools and in the Schools of Second Technical Degree.

Data of a research on demand of human resources in 60 calibration laboratories of the Brazilian Calibration Net (RBC) and 68 tests laboratories of the Brazilian Net of Tests Laboratories (RBLE), totalizing 128 laboratories, shows that, of all the 469 *contracted* professionals, 54% have medium level, 22% superior level, 6% Master Degree, 3% Doctorate and, 15% don't have academic qualification. However, the research reveals that, of all the 118 *trained* professionals, 5% are just of medium level, while 47% are professional with Master's Degree level, 30% with undergraduate level and 18% with level of Doctorate (**FROTA & ALENCAR FILHO & OHAYON, 1998, p. 76**).

The lack of human resources of medium level appropriately trained in Metrology requests the invigoration of alliances between the Second Technical Degree and the Third Degree. A synergy among those two environments of education allows that both can increase the degree of metrological knowledge mutually.

¹ The Brazilian Government's answer for the development of the Engineerings was made through the program **PRODENGE** (Program of Development of the Engineering), initiative created in 1995 by the Ministry of Education and Sports and by the Ministry of Science and Technology. The program is resulting from an action of several agencies that integrate those Ministries aiming at the reformulation of Engineering education in the Country.

Main Metrological Aspects Approached in the Environments of the ETFC - Federal Technical High School of Campos and of the PUC-Rio's Master Degree Program in Metrology

In the environment of the Second Technical Degree, we try to show the general panorama of the metrological knowledge taught and/or that could be taught in different Courses at ETFC and in particular to point out the metrological knowledge essential for the technicians' education in Instrumentation and Mechanics.

In the environment of the Third Degree, it is sought: (i) to highlight the basic curricular framework of the Master Degree Program in Metrology for Industrial Quality of the PUC-Rio; (ii) to aim peculiar characteristics of this Master Program.

The Metrological knowledge Taught in the Different Courses of ETFC

The Federal Technical High School of Campos (ETFC), headquartered in the municipal district of Campos dos Goytacazes, State of Rio de Janeiro, founded in 1909, has a historical commitment with the education of the productive-citizen of the Country. Endowed with modern facilities, ETFC develops a politics of use of computer

based system seeking to the interaction of the educational work, allowing the access to the most important libraries of the Country. ETFC engage 378 teachers of which 1 Doctor, 37 Masters, 6 Doutorate Participants, 24 Master Degree Participants and 220 specialists. The High School has 316 administrative-technician of which 1 with Master Degree, 40 with specialization and 70 with undergraduate level. Nowadays, about 4000 students are registered in the different knowledge areas. The School enables per year about 600 Technicians with education based on the wide integration of the humanistic, scientific and technological knowledge, committed with the educational and scientific research principle (ETFC, 1998).

Starting from 1995, ETFC expanded its campus inaugurating a Decentralized Teaching Unit (UNED), located in the municipal district of Macaé, about 105 Km from Campos dos Goytacazes. At ETFC/Campos, the regular Courses of Second Degree are: Instrumentation, Mechanics, Constructions, Highways, Chemistry, Electrotechnics and Telecommunications. At UNED/Macaé, the regular Courses of Second Degree are: Electronics and Electromechanics.

Table 1 shows the 9 regular Technical Courses where

Table 1: Regular Technical Courses at ETFC with More or Less Contents of Metrology

ETFC COURSES	COURSES THAT OFFER THE DISCIPLINE METROLOGY	LARGER CONTENT OF METROLOGY IN OTHER DISCIPLINES (1)	SMALLER CONTENT OF METROLOGY IN OTHER DISCIPLINES (1)
Instrumentation		*	
Mechanics	*		*
Constructions			*
Highways			*
Chemistry		*	
Electronics			*
Electrotechnics			*
Electromechanics	*		*
Telecommunications			*

(1) As observed in the outlines of the disciplines included in each Course. The personal metrological knowledge of each teacher eventually taught to the students, haven't been considered.

Metrology is taught. It is observed that everybody presents contents in Metrology, even so with more or less degree. Only two Courses (Mechanics and Electromechanics) offer the entitled discipline *Metrology*. It fits to stand out that a higher or lower presence of contents in Metrology in this or that Course doesn't mean that it is inadequate or this one don't attempt to an industrial need.

In the following topic, in a broad way, the relevance of few metrological concepts pertinent to each one of the 9 regular previously indicated Courses is emphasized.

fi Courses of CONSTRUCTIONS and HIGHWAYS

The metrological concepts pertinent to those two Courses, link with the laboratorial part of tests. A metrological evaluation would be fundamental to guarantee the quality of the constructions. The implications on costs and safety may not be neglected. It fits to stand out that trainings demanded in the area of Metrology, evidenced in

recent research on demand of human resources in calibration and tests laboratories (FROTA & ALENCAR FILHO & OHAYON, 1998, p. 169), also concentrate on the civil construction's sector, more specifically in tests laboratories that engage Technicians in Constructions. In this way, the importance of the metrological concepts related to that type of laboratories is observed.

fi Course of CHEMISTRY

In this Course, a significant number of metrological concepts is taught in some disciplines. This fact, evidences the need to have a metrological evaluation system for the measurements made in chemistry laboratories. This metrological evaluation system of measurements is of extreme importance, notably for laboratories linked to health care sector, where the reliability of the executed measurements should be the best possible. Thus, the metrological contents modernization in relation to the recent developments of

Chemical Metrology in the Country is fundamental, mainly about the standardization of the methods and the traceability of the measurements executed in the different typologies of chemical laboratories.

fi Course of TELECOMMUNICATIONS

In the sectors of advanced technology as the sector of Telecommunications, Metrology constitutes an area of decisive knowledge for the evaluation and maintenance of the quality of physical processes associated to the transmission of informations.

fi Courses of ELECTROTECHNICS and ELECTRONICS

These two specialties demand cares, because the use of measurement equipments demands a special attention, once they involve direct risks for their manipulation. Results of the research on demand of human resources in calibration and tests laboratories (**FROTA & ALENCAR FILHO & OHAYON, 1998, p. 169**), show that the specialties where more trainings are demanded, refer to Electrotechnics and Electronics, standing out by this way the relevance of the metrological knowledge requested in these two specialties. This relevance should be justified by the fact that electronics is frequently involved with measurement systems and for this reason has an influence on measurement uncertainty.

fi Courses of MECHANICS and ELECTROMECHANICS

These two specialties present a significant number of metrological knowledge, even so quite exclusively for the specialty of Dimensional Metrology. To assist better industries needs, mainly local industries, it is necessary that the metrological knowledge be also applied for another specialties, as for example Metrology in Flow area, linked to the industry of petroleum production of the region.

fi Course of INSTRUMENTATION

This specialty has, by nature, an intimate connection with Metrology, because in its curricular structure, it presents calibration practices of measurement instruments. Thus, it is important that the taught contents be properly accompanied and up-to-dated, being considered the progresses of Metrology in Brazil and foreign and also the fact that instrumentation is directly related to quality maintenance of measurements realized in industries.

Characteristics of Two Courses of ETFC: INSTRUMENTATION and MECHANICS

Among the nine regular Technical Courses offered by ETFC, it is sought in this topic to highlight just two: (i) The Instrumentation Course concerned by nature with Metrology; (ii) the Mechanics Course as being one of the most traditional. **Tables 2** and **3** just show some disciplines of both Courses in which metrological concepts are important.

Table 2 shows that the teachers that teach metrological concepts have varied education, mainly in the *Professional Practice* discipline, where the laboratory calibration practices request interdisciplinary of metrological knowledges. The metrological concepts effectively taught for the *Professional Practice* discipline correspond correctly to those generally recommended, which no longer was very evidenced in the case of the *Applied Chemical* discipline.

For the Instrumentation Course, the Discipline *Professional Practice* involves an approach that allows to the student a better evaluation of the *time of recalibration* of each measurement instrument. The determination of the *time of recalibration* of an instrument is fundamented, on one side, in its physical process of measurement and, on other side, in the production process and in the constancy of use of this instrument.

For the *Applied Chemical*, it is verified that an important developed concept is the *traceability* concept for reference materials that guarantees the reliability of the measurements.

For the Technician in Instrumentation, it is essential a good knowledge in evaluation and estimating of *uncertainty measurement* and in the uncertainty associated to calibration certificates and to the use of this important calibration result for measurements.

For the Mechanics Course, it is observed in **Table 3** a great diversity of applications of metrological concepts for different specialties of Mechanics. The Discipline *Metrology* should not limit itself to the *Dimensional* specialty, but to extend the metrological applications to other specialty as for example: *Thermal, Fluids Metrology* that includes Metrology in *Flow* area, useful for oil industry of the region.

Regarding the *Technology of Materials and Tests* discipline, at least at the level of the Second Degree Technical School, it is necessary that the concept of *metrological reliability* be approached in different mechanical tests, as for example tests of *Hardness*.

Table 3 shows that all the teachers that teach metrological concepts for the mentioned disciplines have mechanical education, expliciting the strong presence of concepts regarding to the area of *Dimensional Metrology*. Comparing the concepts effectively taught with those considered the ideals for a better metrological education by Technicians in Metrology, it is observed that the discipline *Metrology* requires a strong interdisciplinarity. This fact would imply in a new curricular formulation for mechanical engineering courses concerning its metrological education.

Table 2 - Relevant Metrological Concepts in Few Disciplines of the Technical Course of INSTRUMENTATION

DISCIPLINES ⁽¹⁾	MAIN METROLOGICAL CONCEPTS RECOMMENDED	MAIN METROLOGICAL CONCEPTS TEACHED	ACADEMIC EDUCATION OF THE TEACHERS
Applied Chemical	- accuracy analysis and tests uncertainty - formalization and standardization of procedures	THE DISCIPLINE DOESN'T PRESENT METROLOGICAL	1 Undergraduate

	- traceability/reference materials - characteristics of Chemical Metrology - repeatability/reproducibility	CONCEPTS	in Chemical
DISCIPLINES⁽¹⁾	MAIN METROLOGICAL CONCEPTS RECOMMENDED	MAIN METROLOGICAL CONCEPTS TAUGHT	ACADEMIC EDUCATION OF THE TEACHERS
Professional Practice	- calibration (general theory) - calibration periodicity - analysis of measurement errors - calibration bench (generic) - traceability - measurement uncertainty - measurement system (general theory) - standards hierarchization - normalization/quality - repeatability/reproducibility	- calibration bench (pressure, temperature and flow) - measurement system - dimensional metrology - normalization/quality - controller's calibration	2 Undergraduates in Mechanics 1 Undergraduate in Instrumentation 1 Undergraduate in Data Processing 1 Technician in Mechanics
Industrial Instrumentation	- reference materials - International Metrology Vocabulary	- International Metrology Vocabulary	1 Undergraduate in Mechanics 1 Technician in Instrumentation

(1) Disciplines where effectively metrological concepts are or should be taught;

(2) In agreement with the nomenclature used by INMETRO.

Table 3 - Relevant Metrological Concepts in Few Disciplines of the Technical Course of MECHANICS

DISCIPLINES⁽¹⁾	MAIN METROLOGICAL CONCEPTS RECOMMENDED	MAIN METROLOGICAL CONCEPTS TAUGHT	ACADEMIC EDUCATION OF THE TEACHERS
Metrology I and II	- dimensional metrology, fluids, forces, mass and ⁽²⁾ - thermal - calibration and certification - measurement uncertainty - certificates (formalization of calibration results) - origins of the measurement uncertainty - theory of errors - International Metrology Vocabulary	- Dimensional Metrology - Theory of errors	2 Undergraduates in Mechanics 1 Technician in Mechanics
Technology of Materials and Tests	- tests analysis - metrological reliability - tests normalization (procedures) - expression of uncertainty in tests	- tests analysis - tests normalization	3 Undergraduates in Mechanics 1 Technician in Mechanics

(1) disciplines where effectively metrological concepts are or should be taught;

(2) in agreement with the nomenclature used in INMETRO

Finally, it is observed in the two analyzed courses, the lack of a dissemination of the concept of *Measurement Uncertainty* that should not be confounded with other concepts such as *Accuracy*, *Precision* and *Error*. The translation in portuguese of these terms used in manuals and in technical specifications of different equipments and written in other languages, requires serious cares.

Main Characteristics of the Master Program in Metrology for Industrial Quality of PUC-Rio

Created in 1941, the Pontifical Catholic University of Rio de Janeiro, PUC-Rio, is the first private university of the Country. PUC-Rio

counts about 10.000 undergraduate and 1.600 graduate students, 23 Departments distributed in three centers: Scientific and Technical Center (CTC), Center of Theology and Human Sciences (CTCH) and Center of Social Sciences (CCS) besides the Center of Biological and Medical Sciences (CCBM).

CTC includes the Departments of Basic Sciences and of Engineering. It counts with 200 faculty members/researchers with Doctorate Degree obtained in the best domestic and foreign universities. CTC considers that the best education is the one that results on the called *entrepreneur professional with scientific basis (REENGE/PUC-Rio,1997)*.

The proposal of PUC-Rio for the National Program of Education

and Training of Human Resources in Metrology (*RH-Metrologia* Program), was developed starting from the understanding of the problem of Metrology in its two dimensions: horizontal and vertical. The horizontal dimension elapses of the fact of Metrology be multidisciplinary, covering several areas of the knowledge. The vertical dimension results of the fact that Metrology covers the whole spectrum of education, from the graduate level to the fundamental education. For these reasons, teachers formulated activities that cover from the interaction with Primary Schools and High Schools until to the proposal of a Program of Master in Metrology for Industrial Quality, begun in August 1996, which contends the accomplishment of scientific Metrology dissertations with strong applications in industrial problems.

The Master Degree in Metrology objective is to

prepare human resources to supply the needs of: (i) the National Metrology, Normalization and Industrial Quality System; (ii) the National Metrology Laboratory (LNM); (iii) the laboratories that belong to the Brazilian Nets of Calibration and Tests; (iv) the industrial laboratories and service firms; (v) educational institutions, research and technological development institutes (*PUC-Rio, 1998*). It counts now (March 98) 28 students, being 17 in phase of Dissertation elaboration. The Program has as peculiar character: interdisciplinarity, interdepartmentality and professionalization. In this way, the teachers try to guide the students for the elaboration of Dissertations oriented for the solution of a concrete problem more than for the elaboration of a traditional Dissertation, *monographic*.

Table 4 - Application of the Contents of the Disciplines in the 7 Lines of Actuation (Teaching and Research) of the Master Degree in Metrology of PUC-Rio

		Application in the Lines of Actuation of the Master in Metrology						
		Ther	Mec	Opt	Norm	Chem	Env	Mot
	Fundamentals of Metrology	*	*	*	*	*	*	*
	Normalization and Industrial Quality	*	*	*	*	*	*	*
O	Statistical Methods for Metrology	*	*	*	*	*	*	*
	Numeric and Computational Methods	*	*	*	*	*	*	*
	Instrumentation and Signs Processing	*	*	*	*	*	*	*
	Optical Measurements e Optoelectrics			*				
	Ionizing Radiation			*				
	Electric, Magnetic, Time & Frequency Measurements			*				
	Metrology in Chemical					*	*	
	Laboratory of Chemical Metrology					*	*	
	Temperature Measurements, Pressure and Flow	*						
E	Polluents Measurements					*	*	
	Thermophysics Properties Measurements	*				*	*	
	Dimensional Metrology		*					
	Acoustics and Vibrations in Metrology		*					
	Force, Deformation and Displacement Measurements		*					
	Advanced Techniques for Quality Control				*			*
	Management of Technology I: Technological Innovation	*	*	*	*	*	*	*
	Management of Technology II: Firm's Technological Strategy	*	*	*	*	*	*	*

O = Obligatory Disciplines; E = Elective Disciplines; Ther = Thermal; Mec = Solids Mechanics; Opt = Optical, Ionizing Radiation and Electricity;

Norm = Normalization and Industrial Quality; Chem = Chemical; Env = Environment and Mot = Management of Technology.

Table 4 highlights the 5 Lines of Actuation, the 5 Obligatory Disciplines and the 16 Elective Disciplines of this Master Degree in Metrology of PUC-Rio (of which 3 at least should be studied), linking the Disciplines to the Lines of Actuation. Whole the basic or Obligatory Disciplines have application in the 5 Lines of Actuation of the Master Degree Program. In fact, an Obligatory Discipline as for example *Fundamentals of Metrology* offer basic concepts that can be applied to a great diversity of areas of knowledge. With relationship to the 16 Elective Disciplines, it is observed that 6 act in an unique Line of Actuation of the Program, 4 in two Lines, 1 in three Lines and, finally, two in whole (Management of Technology I and II).

The industrial application of the knowledge acquired by the students is expressed in **Table 5**. Among the 17 students in initial phase, more advanced phase or end of elaboration of Dissertation, 12 are Engineers (being 6 formed in Mechanical Engineering, 4 in Electric Engineering, 1 in Electronics, 1 in Metallurgy), 1 is undergraduated in Data Processing and 4 are Physicists.

Table 5 shows well how by Metrology it is possible to integrate knowledge of different specialties. It is observed, as examples, an undergraduated student in Physics, acting in the Specialty of Mechanics according to the Actuation Area of LNM/INMETRO, developing a research in the field of Flow close to the research center of the national oil company; another one, undergraduated in Electric

Engineering, acts in the Specialty of Mechanics, developing Dissertation in the field of Optical.

The works developed by the students and teachers show the need to strengthen alliances, based in the reciprocity sense and focus in

solid joint actions (with clear partition of responsibilities, allocated time, cost and performance), contributing to the solution of concrete problems, being Metrology one of the fundamental tools of whole this process.

Table 5 - Basic Education of Master Students in Metrology of PUC-Rio, Chosen Specialties and Adherence to the Areas of Actuation of the LNM - *Laboratório Nacional de Metrologia* /INMETRO

INMETRO Æ		mechanics	electricity	thermal	optical	acoustics	ionizing radiation	time & frequency
Ø PUC - Rio								
1	flow	1 physicist 1 electronics engineer						
	viscosity	1 physicist 1 mechan. engineer						
	temperature			1 mechan. engineer				
2	hardness	1 mechan. engineer						
	acoustics					1 mechan. engineer		
	metallography	1 metallurg. engineer						
3	electricity		1 physicist 1 electric engineer					
	electromag waves				1 electric engineer			
	volume		1 electric engineer					
	optical	1 electric engineer			1 mechan. engineer			
4	norms	1 mechan. engineer						
5	pollutant			1 physicist				
6	management of technology (mass)	1 undergrad in data processing						

Analysis and Recommendations to Increase the Effectiveness of Alliances between Third Degree and Second Technical Degree in Metrology

In one moment in that the Country is conscious of the need of reviewing all its educational system, two convictions encourage the debate on the invigorations of the necessary alliances among the different actors of this system: on one side the necessary *renewal* to the teaching of Metrology requests a joint action of all its actors; on another side, the education comes to pass henceforth along an entire life. The objectives, the methods, the programs of Metrology education, so much in the Second Technical Degree as in the University should be reviewed taking into account this new fact.

The reasons for which the renewal is necessary and the general conditions for which this happens are initially presented. Later on, the growing influence of the industrial sector in Metrology education is analyzed. The following topics are about the education in the Second

Technical Degree. The masters' education conditions the future of this renewal in the technical teaching. The last topics are consecrated to that motivates all those efforts and cares to the renewal of the Metrology education and to raise the students' interest: a fan of interesting and gratifying careers offered by industry; the possibility for any actor of Metrology in having a vision of the world and a stimulating cultural enrichment.

fi Necessary Renewal: Reasons and Conditions

- The world is in full mutation and the elevated acceleration of the elaboration of scientific knowledge and, in parallel, of innovations and outcomes of the technique constitute one of its main causes.
- The Metrology education is still very centralized in few educational institutions, where the autonomy to act is reduced.
- Metrology, science of measurements, which is at the same time science, technique, industry, and the technical base of quality,

constitute a fundamental body of knowledge for technology. *RH-Metrologia* Program (**FROTA, 1998**), initiative of three Ministries (Education and Sports; Science and Technology; Industry, Trade and Tourism), coordinated by the Directorate of Scientific and Industrial Metrology of INMETRO, has the advantage to facilitate and integrate analysis on concrete cases of specialized human resources education and to formulate valid conclusions for the group of another bodies of scientific and technical knowledge. The theme Metrology propitiates in this way a forum of deepened debates where engineers and industrial can dialogue with teachers of Third Degree and Second Technical Degree.

- The necessary renewal of the Metrology education system cannot only be a reserved subject to teachers. Companies should consider its participation to the Second Technical Degree youths' education and to the Third Degree adults' one as one of its missions, today essential.
- What is new and deserves to be taken in consideration is the need for the companies to pursue its employees' education in its technical activities, in particular in the field of Metrology. In fact, the speed of technical evolutions and the implications in the field of Metrology, favored by the competition in the world scale, imposes to companies to assure the continuity of the metrological education.
- Metrology should be object of new accreditation close the Ministry of Education for undergraduate level and not just for masters degree, contributing to supply better the Second Technical Degree and the companies. This recommendation results of the pressure for the demand for metrological services (two hundred thousand certificates of calibration and tests reports emitted by year) moving more than one hundred and twenty million dollars/year (**FROTA & ALENCAR FILHO, OHAYON, 1998, p. 137**).

fi Metrology in the Second Technical Degree Education

The renewal effort should pursue a double objective: (i) to propitiate, in the short term, for students of Second Technical Degree, a gratifying employment; (ii) to revalue the technical education, in particular in Metrology, in the Brazilian society. For so much several conditions should be satisfied, as:

- to assure an initiation to technology.
- to do that the technical education be a cultural education as such, attracting a growing number among the most endowed students and for so much, to show that this education offers good employments or development possibilities.
- knowledge don't constitute the only objective of education. It is necessary to develop beside the knowledge, know-doing (*hands-on*), know-organizing, know-documenting, know-behaving and know-working in team. The librarian's importance comes growing and becomes indispensable in Metrology. The students' life should constitute the first of the concerns for the responsible of
- education programs in Metrology. Thus, it is necessary to value in the education process the *monitoring* and the *orientation* and not just the *selection*, so that in this way to assure the indispensable continuity of the Metrological activity in the formed Technician's professional life.

- It seems more important to develop the liking and the capacity of learning than to multiply the knowledge that the student should learn. The students should be habituated to work more and more in atmospheres automated and to take in account complex factors. It is important that programs oriented to high abstraction, don't come to decrease in the student the liking, the contact with material (experimentations), depriving him of an irreplaceable source of intuition and of intelligence.
- Classic methods of teaching seem insufficient to prepare the future teacher and student of Second Degree Technical School. Hence, the need to find an innovative pedagogic form that, without harming the acquisition of the fundamental notions of Metrology, would dive the teacher and the students in the action and would wake up the creativities of these last ones: an education of the curiosity and of the ingeniousness. The *learning by action* (**GERMINET, 1997**) cultivates the interrogation, the curiosity and the creativity of the future Technicians in Metrology for the accomplishment of a series of experimentations. The *learning by action* creates in the student a strong obligation for obtaining result. The experiences are unchained one after another. It is impossible to pass to the next without having solved the previous and therefore to have understood the indispensable physical principles for the studied effect. The students as well as the teacher are incited to *accomplish* and not just to *conceive*. A notorious example of this learning way is given by the Didactic Laboratory of the Physics Institute of the Federal University of Rio de Janeiro (LADIF/UFRJ) which, notably through the laboratory practices, helps teachers and students of Undergraduate and High School Degree to use better the theoretical concepts for *Experimental Physics* education.
- During a lot of decades, the Metrology teaching was assured by teachers of Physics. Physics teacher of today didn't generally have contact with engineering teachers. Furthermore, the Physicist, the Engineer and the Technician of Second Degree have very different visions and perspectives of Metrology. The lack of technological sensibility in specialization programs in University justify this fact partly. The ideal would be that the teacher of Metrology of the Second Technical Degree had a real education in Metrology. This perspective being just possible at medium and long range, two possible recommendations able to be operationalized in short term are suggested: (i) make participate students and teachers of Master and Doctoral Programs of Metrology in all instances and commissions where Metrology programs are taught in the Technical Schools of Second Degree, producing notably apostils, promoting seminars and workshops. This initiative should be motivated because it makes secure the capacity to teach, it strengthens necessary alliances and, it allows to apply knowledge requested by the demand forces. *RH-Metrologia* Program (action Number 6), coordinated by the Directorate of Scientific and Industrial Metrology of INMETRO, favors this initiative (**FROTA, 1998, opcit**); (ii) create Requalification Programs during the long period of vacations (summertime), for Metrology teachers of Second Degree Technical Schools, offered by teachers of several universities of a same city (or of different cities using in this way recent distance education facilities), involving in this initiative the calibration and tests laboratories (of the industry and technical education institutions of the National Industries

Confederation, of the universities and research institutes, of the metrological service firms and of INMETRO).

Metrology in University Education (Master Degree of PUC-Rio)

While in the technical education of Second Degree, Metrology is still not very present, it appears in the Third Degree, in the undergraduate and graduate levels, as science and as technology inducing for the construction of objects (for example, measurement instruments). The spectrum of Metrology action comes growing mainly when, on one side, Metrology is benefited itself from the considerable progresses that the more recent discoveries of Physics propitiate for experimentation, and on another side, when the machines or the apparels take in consideration thermal, energetic, electronics properties and integrate facilities offered by computer science and by automation.

- Although it is convenient to distinguish these two education poles in Metrology (scientific education and technological education), it is necessary for the overall spectrum of education from the Second Technical Degree to the more advanced levels of the Third Degree a necessary continuity be respected.
- The education in Metrology requests synergy with research and with industry. An immersion of two months in industry by students and teachers of the Master in Metrology Program of PUC-Rio, before the final defense of the Dissertation would be useful, notably for those that want to be Masters in Technical Schools of Second Degree.
- The synergy with Second Degree Technical Schools and with industries potentially interested to recruit students with solid metrological knowledge from these Schools, allows to strengthen in the Third Degree a better technical education, still so lacking, without renouncing to the traditional scientific education. This synergy can be larger with the reform and invigoration of the Second Technical Degree, preconized in 1997 by the Ministry of Education, with resources coming from international loans (about five hundred million dollars for a horizon of more or less five years).
- In this decade, Metrology comes growing so much in the academic sector as in the industrial sector. The Masters Degree in Metrology Programs receive good concepts for the Ministry of the Education. The value of the Diploma in Metrology seems to be appreciated. In this way, for Metrology be recognized better, it should be convenient to create new education programs in Metrology in Universities where these one don't exist.
- The students' metrological knowledge of Second Degree Technical Schools as well as of the Third Degree are not always well used by that recruit them. It is necessary to prepare students able to develop a precise activity. The conditions to assure the success of this initiative are numerous. The essential condition is that the educational institution and the company be absolutely in accordance to assume the students' education jointly. This implies responsibilities distributed since the education definition and the effective determination to steer the work in common, being respected the particularities of each part. The suggested alliances are, on one side, between educational institution and industry (initiative that is increasing) and, on other, alliance Technical Second Degree-Industry-Third Degree in Metrology.

- One manner to make effective the alliance between Third Degree and Second Technical Degree would be the institutionalization of a new requirement for the obtaining of Master's title in Metrology which would be the professional practice of the graduate student into Technical Schools of Second Degree.

fi Metrological Culture

Metrology is a component of the culture. It is source of scientific and technical culture. By the fact of being at the same time science, technique and industry, Metrology contributes to transfer acquired knowledge among those three components of the human activity and strengthens the mutual interactions. The Metrologist meets in a privileged position of observation, allowing to assimilate and understand these transfer phenomena and these interactions.

In universe of culture, and in particular of metrological culture, the center is everywhere: notably in mathematics, in physics, in chemistry, in biology and in engineering. Thus:

- a solid metrological education assures an extraordinary educational coherence, being constituted as a factor of integration. In this way, the education should be valued for and by Metrology. This basic knowledge of Metrology should be prolonged and evolve along all the life for those who develop its professional activities.
- The metrological education, by the diversity and integration of different knowledge, suggests an ability for a professional to coordinate and to value the contributions of the different knowledge areas so much as the multiple professional activities that conduct to the development of technical project conceived by himself and for which he is responsible.
- Metrology is still today rarely noticed as a culture for several reasons: (i) lack of conscience of unity of the Metrology; (ii) specialization of knowledge in detriment of fundamentals; (iii) tendency in excluding Metrology of the basic scientific knowledge.
- It is suggested the creation, in the ambit of SBM - Brazilian Society of Metrology, constituted in 1995 and headquartered into INMETRO, of a Committee for integration Third Degree - Industry - Second Technical Degree, in the metrological field, aiming at the dissemination of knowledge that interest the three parts. This Committee should have available a monitoring and evaluation of impact instrument of the students' training, teachers and professionals of industries involved in that alliance, allowing a better understanding and adaptation of Metrology education to the real needs of industry and other agents of economic and social development of the Country.
- The image of Metrology in our society is tied up to the perception of its cultural, economic and social value. The social perception can only be perceived if the own actors of Metrology perceive it and live it. The Brazilian Society of Metrology (*SBM, 1997*) constitutes an excellent forum for integration and alliances, aiming at an useful debate that values the traditions and Brazilian culture.

fi Mission and the Education of the Masters in Metrology

The education of those that will become so much teachers in Metrology in Technical Schools of Second Degree as in the Third Degree, should stand out the personality qualities that should be raised, educated and developed in the teachers' initial education. For so much, several conditions are imposed, as:

- to do reference, during the process of the future teacher's of Metrology education, to the objectives and the practices of industrial companies. This constitutes a warranty of realism and quality. Furthermore, the teacher of tomorrow is incited to maintain alive this reference the whole life. The teachers are recruited for many years. During all that period, technological mutations will occur. Thus, it is useful to assure the scientific and technical fundamentals on which they can lean on and to modernize their competences, notably taking advantage of relationships built with companies and of requalifications propitiated through extension courses.
- to raise and to favor national or local *net* constitution able to integrate University-Industry-Technical School of Second Degree. This net, conceived initially for information in technological services by **FROTA, M.N. & FROTA, M.H. (1994)**, would have a surveillance mission, of studies and of propositions, assuring the necessary adaptations in an atmosphere where Metrology is not still so well-known and sometimes suffers of an unfavorable image. The role of Metrology teacher is primordial for improving this image. The net constitutes an excellent mobilization and reevaluation forum of that image.

Final considerations

The reflections, the suggestions for improvements and the indicated set of different actions in this paper, seek to increase the quality of available workforce in Metrology field, integrating the Third Degree and the Second Technical Degree, aiming to attend better the Government in the formulation of politics that should contribute to strengthen the competitiveness of national industry.

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