Practice-Based Course in Instrumentation and Measurement for Working People

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Abstract: A whole course in Instrumentation and Measurement Science, primarily devoted to working people, has been established and developed in Paris (France), at the *Conservatoire national des arts et métiers*. Lectures are delivered as well at working time (as commercial training) as during after work hours in the evening (as state-supported training). The academic staff in measurement science belongs to the french BNM, i.e. the *National Bureau of Metrology*, and many lectures and examples rely on industrial subjects.

Organised around a coherent construction of modules that everyone can pass to his own rythm, the course tends to deliver national degrees and diploma for technicians and engineers in Instrumentation and Measurement, with three different more specific specialities: Metrology and Quality, Optics applied to industrial measurement, Control of process.

The teaching program tries to deeply take into account the knowledge acquired by the students during the time that they are spending at work, outside the teaching institution. The last part of the engineer course is a one-year practice project realized directly in the company of the student or in an equivalent situation. Working people can choose to attend and pass in the course the modules that they mainly need, according to their present or future activity : either a simple initiation, or a qualification, or a more elaborate competence in instrumentation and measurement, besides their own initial or present speciality.

Lectures are delivered in several french major cities to match the professional requirements of the students. Part-time « distance teaching » has also been implemented for a limited number of modules.

1. Introduction

CNAM, i.e. *French National Conservatory of Arts and Trades*, is a major public national high education institution. CNAM promotes the professional advancement of people and the development of technical skills ands crafts. CNAM has recently re-organized its practice-based program in Instrumentation and Measurement.

2. Practice-based education in Cnam

2.1. Heir of the french revolution

CNAM (Conservatoire national des arts et métiers) is one of the four institutions for high education established in Paris in the late eighteenth century (1794) which are still alive, together with ENS (Ecole normale supérieure), X (Ecole polytechnique) and INALCO (Institut national des langues et civilisations orientales), and is today in charge of several missions roughly unchanged from the beginning. Heir of the french revolution, CNAM was created « to ensure that everybody can learn and have benefit from the new objects, machines, drawings and techniques useful to the *Arts and Trades* », that is to say to the industry and the entire society. In the early days CNAM was giving lectures and demonstrations about the use of machines and techniques in a broad range of domains : industrial science and techniques but also business ans management (with J.B. Say as the first professor of *Economics*). A wide public of adult people was attending to these general demonstrations and conferences. Such type of daily general conferences has been initiated again during the millenium year 2000.

2.2. A technical university network for workers

Today, the collection of machines and technical drawings has turned to a technical museum, the so-called *Musée des arts et métiers,* entirely renewed during the last decade, and a scientific and technical library. The teaching activity has been developed in such a way that the theoretical and practical lectures are given in more than fifty different cities in France and abroad (of course, not every lesson everywhere) and that roughly 80 000 working adult students are attending the lessons, which are given either during business days (as commercial training courses) or mostly in the evening or on saturdays, that is to say out of business time (as state-supported training). Management, business science and computer science are the fields where students are most numerous, but many engineer specialities are taught.

2.3. Towards diploma

The relevant courses tend to deliver national diploma for technicians ans engineers. They are made of a coherent construction of semi-independent modules that everyone can pass to his own rythm, in one or several places in France according to his own professionnal mobility. To get the diplom, one has to pass the whole set of modules, but also to make the proof to a specific committee of a professional working experience in the speciality. Higher the postulated level of diplom is, longer the requested experience should be. So the teaching program deeply takes into account the knowledge acquired by the students during the time that they are spending at work, outside the teaching institution.

The last part of the engineer course is a one-year practice project realized directly in the company of the student or in an equivalent situation.

Of course, a large number of students do not attend lectures to get diploma (they already have some): they come to perfect themselves in their own speciality, to acquire a second competence in a new field, especially in a transverse field (as it can be the case in Metrology), to initiate a move or a change in their professional activity, or even to prepare a more general full-time training course anywhere else.

2.4. Academic and professional equivalences

Most of the students got some initial degree previous to their employement, or to their employement in the speciality where they are now working and attending lectures. They can be eligible to a large number of « academic equivalences ». But practice-based modules are usually very specific to CNAM and only very few exemptions can be obtained.

Furthermore, many people have experienced during their professional activities the topics covered by the academic lectures. That is in fact in this way that one has to understand the expression *experience in the speciality*. In some cases, the specialised work done by a student, the level of autonomy and responsability he or she is exerting, make it relevant to check whether attending an academic module in that field has any interest. A specific -- and long -- procedure exists to ensure the adequation between the experience and the topics of the lecture and to give an exemption to the student according to « professional equivalence ». The main difficulty in the development of such a procedure relies in the fact that lectures are mainly described as topics and contents, as professional experience appears in terms of competence. Most of the academic modules had to be thought again in terms of « capacities to acquire » and no longer in terms of topics.

3. Instrumentation and measurement.

3.1. The development of metrology

The metric system has been established 1793 by the French Congress (*la Convention*) a few months before the creation of CNAM.. The production of etalons for the new units, and the dissemination of those among the manufacturing companies, correspond exactly to the above mentioned purpose of CNAM. A metrological laboratory was created in CNAM during the XIX° century. It played a major role at the time (1875) of the preparation and the signature of the *Convention du Mètre* (the international treatise defining and organising the

evolution of the International system of units (SI), still alive), achieving the calibration of many of the platinum mass and length prototypes disseminated at that time among the nations. Nowadays this laboratory (BNM-INM) develops national and international research programs in fundamental metrology. It is one of the components of the French National Bureau for Metrology, and it is working as the primary laboratory for length, mass and derived units, temperature, radiometry and photometry.

3.2. Teaching measurement science

Despite the fact that physics has been taught in CNAM almost from the beginning, one has to wait until 1932 to find in the schedule of the lectures a first « Metrology course » by P.Fleury. The number of students has been increasing in the past decades, and now there is a complete program, with introductory levels taught in a various number of other engineer specialities (electronics, mechanics, energy science, etc.), and different complete programs in measurement science : an engineer course and a graduate program.

The engineer course is entitled ***Instrumentation and Measurement***. It is proposed to working people and has been recently renewed to fit this particular type of listeners : it takes into account the major capacities that are needed in the industry to work in Measurement science at a responsability level higher than operator or technician.

The first part of the course is formed by several modules in :

⇒ Physics of sensors
⇒ Instrumentation (Data acquisition, digitalisation)
⇒ Metrology (Expression of uncertainty, traceability, data analysis)
⇒ Control (Analogic controlling and retroaction)
⇒ Mathematics for signal processing
⇒ Experimental practice-based examples in Instrumentation (a doubble module which includes four parts : general experiments in measurement science, specific optical methods for measurements, low signal detection and noise suppression techniques, introduction to software-assisted instrumentation).
⇒ and one optional modules in Optics, Microprocessors, Electronics for measurement, etc.

At that stage one has to profe his own ability to mix the different concepts studied during a project of two months coupled with industrial subjects, resulting in a bibliographical study and a defense of the results obtained. This so-called *probation exam* is one of the major difficulties on the way towards the degree.

Then, students choose one of the three following optional studies, according mainly to their professional activity which is controlled as explained previously :

- **Optics**
  - ⇒ Image processing
  - ⇒ Modulation techniques, or Laser measurements, ...
  - ⇒ Signal processing
  - ⇒ Experimental optics, instruments
- **Metrology and Quality**
  - ⇒ Quality in measurement
  - ⇒ Signal processing, or digital control processing
  - ⇒ Radio-photometry, or Thermometry, or Laser measurements, or Metrology in electricity and magnetism...
  - ⇒ Experiments in high precision measurements.
- **Control of process**
  - ⇒ Computer science for industrial production (theoretical and experimental modules)
  - ⇒ Signal processing
  - ⇒ Digital control processing

The detailed content of the studies can be modified according to each professional case using a large set of equivalences. Each module is 60 hours teaching time long, but required a lot of personal work so that it is not

possible, in the best case, to pass more than five to six modules a year. several modules are also proposed as training during working hours.

3.3. Engineer practice-based abilities

Students have also to learn Management (2 modules) and Communication (1 module). The ability to speak one foreign language with a sufficient level is checked to get the degree (english at 99%...).

The last active part of the studies is a personal one year project, generally in the company where the student is working : the subject should correspond to a work *oftenly assumed by engineers* and should also fit the speciality choosen. Tutorial sequences occur, at CNAM and in the factory, with two supervisors (one in each). A written summary and a defence of the resultas are organised. As examples, the project can lead to a new type of electric energy autoconfigurable counter for the public electric service, or to a new calibration method for motors fixing the position of power antennas embarqued on satellites, etc.

This last part of the program fit quite well the professional situation of people working in Measurement science, who have a previous technical speciality on which they exert their new competence in metrology.

More than 30 engineers get the degree each year in this speciality, the main fraction outside Paris (800 for the whole CNAM). The mean duration of the studies, from Bachelor to Engineer degree, is six years.

4. Conclusion

CNAM has developed, by the way of courses specifically devoted to working people, a complete program in Instrumentation and Measurement. This type of practice-based teaching is particularly relevant in the case of metrology, as the development of this transverse speciality corresponds usually to a second competence acquired during a professional career.