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Thoughts on the education in measurement and instrumentation: A review of requirements

Mauricio N. Frota [a,*], Ludwik Finkelstein [b,1]

[a] Postgraduate Programme in Metrology: Metrology for quality and innovation, Pontifical Catholic University of Rio de Janeiro, Rua Marquês de São Vicente, 225, CEP 22453-900 Rio de Janeiro, Brazil

[b] Measurement and Instrumentation Centre, School of Engineering and Mathematical Sciences, City University London, Northampton Square, ECIV OHB, UK

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ABSTRACT

The paper examines the requirements for new information technology tools for education and training in measurement and instrumentation, given the advances in capability of information technology. A review is presented of the capabilities and limitations of educational tools. It is argued that the requirements are affected by the widening global spread of the application of measurement and instrumentation technology, the increasing importance of the metrological perspective of the discipline, the need for education and training at all levels (not only at the advanced scientific level), and the importance of resource limitation.

1. Introduction

The application of new information technology tools to education and training in measurement and instrumentation is a significant innovation, which presents prospects for important developments. There are two drivers of innovation: technology push and requirements pull. The first exploits technical possibilities, providing solutions in search of applications. The second identifies problems and seeks innovative technical solutions.

Given the strong technology push, the authors examine the requirements pull for new information technology tools to be applied to education and training in measurement and instrumentation. They base the examination on their long-term experiences in implementing interdisciplinary centres for education in measurement science in their own institutions [1–5] and on the results of a round table jointly coordinated during the IMEKO World Congress [6].

2. The nature of the discipline

There is currently a lively interest in the definition of the name, nature and scope of measurement and instrumentation science and technology, as well as a wide range of views on the topic. Two different perspectives on the discipline are current. One is the systems and information view of the domain. It may be given the name as measurement and instrumentation science and technology. The other is described by the name metrology.

The central basis of the first view is the consideration of measurement as an information process, and of measuring instrumentation as information machines [5]. The discipline is seen as closely related to the sciences of systems and information. It shares with them the use of mathematical models of physical systems, the application of the concepts and methods of signal representation and processing, and the systems approach to the design of measuring systems. Its special problems are sensors, the interface between sensor and measured system, and error analysis. Units, standards and calibration were seen as an important, but not central, area of the discipline.

The progress of science and technology reinforces that view of the discipline. To an increasing extent measuring

* Corresponding author.
E-mail address: mfrota@puc-rio.br (M.N. Frota).

[1] In memoriam.

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instrumentation is implemented by standard information technology and relies on the underlying science. The technology of sensors is increasingly like that of the hardware elements of computing. New techniques, like sensor fusion, rely on the science and technology of information processing. The way forward, from this point of view, appears to be the treatment of measurement and instrumentation science and technology as a special sub-discipline of the sciences of systems and information. This viewpoint appears very fruitful technically, particularly in the design of measuring systems and in the application of measuring instrumentation in automatic control.

However, recent developments have also made obvious the increasing importance of metrology, viewed as being concerned with standards, calibration, the measurement process and measurement uncertainty [7]. Two factors may be thought to be the cause of that importance. The first is the increased need for all industries to maintain high, verifiable, quality. Quality assurance is based on metrology. The second factor is the fact that while only a limited number of countries have a major effort in the design and development of measuring instruments and systems, all countries of the world require a sound base in metrology. This must form the focus of international co-operations. Since there is an established and accepted definition of the name Metrology as the science of measurement in general, it might be thought to be the most appropriate name for this view of the discipline.

Different approaches to education and training are appropriate to these two viewpoints.

3. Formation

Learned society discussions on education and training in measurement and instrumentation have in general concentrated on the professional academic education of scientists and engineers. This is a narrow perspective. It is proposed here to take the wider perspective of the formation of human beings [6,7].

Formation is a process of three components: education, training and continuing development. It has formal and informal parts. The reflections here focus on formal education and training, inculcated through courses and the like. Informal experiential learning, whether or not recognised as relevant before the education community is left to another discussion.

The components of formation may be defined as follows. Education inculcates knowledge, attitudes and intellectual skills. Training is concerned with the development of specific practical skills. Continuing development is a lifelong process of acquiring new knowledge and skills, as well as developing broader and more mature attitudes, as society changes, science and technology advance, and careers progress.

Education and training in measurement and instrumentation have always concentrated on technical professionals and their preparation for their professional work. This is too narrow. The ability to measure and to apply measurement is a capability that all people must have so that they can function in modern society. It is also important to recognise that formation is not only intended to prepare learners for work, but also to fit them to function as individuals and as members of families and of society as a whole. As professionals they must be formed not only for their initial employment, but also future developments of technology and society, and for development of their career in which they may perform various functions. Ultimately they are also formed for their retirement. While learning, in a modern society, must be a process of lifelong continuing development, it must be recognised that the essential function of all education and training must be a preparation for further learning.

Measurement is a key concept and enabling tool of all knowledge; its significance, while of primary importance in natural science and technology, is also central to all other knowledge.

The ability to measure and apply measurement, and understand the uncertainties associated with measurements of all kinds, must be inculcated in all primary and secondary education. An understanding of the some of the principles of natural science and the methodology of science is an essential part of all education. This must be based on the understanding of the nature of measurement and experience of its practice. Actual measurement practice is a vital part of education. The processing and interpretation of measurement results, and the handling of measurement uncertainty, must form part of education in mathematics at all levels. The concepts of measurement and uncertainty should form part of education in social studies and to some extent in the humanities.

To turn now to the education training and development of technical personnel it is necessary to distinguish different levels of expertise. Among them, one may distinguish: craftsmen, technicians, technician engineers, and scientific engineers. The names are not agreed in all languages and cultures, but the levels of competence are recognisable everywhere. Craftsmen are generally expert in good practice and in manual skills. Technicians have the practical expertise of craftsmen, but are educated to have an understanding of the basic principles underlying their work. Technician engineers are educated and trained in both the science and practice of their speciality and are able to apply established practice to problems of some size and complexity. Scientific engineers are educated in both science and practice to a level which enables them to advance knowledge, innovate and tackle problems that are new and complex. They are formed to provide technical leadership.

In the education and training of all levels of scientific and technical personnel, we may distinguish the basic education in the ability to measure, which must be acquired by all natural scientists and engineers, and is generally provided by laboratory courses. A higher level of attainment in measurement and instrumentation, which we may call ancillary, is required by engineers in a number of specialisations, notably control engineering. The highest level of attainment is required by those who will engage in design of measurement instrumentation.

It is important to recognise that all levels and types of expertise are important and must be considered in the development of supporting tools.